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Virtual Operations Center for Smart Maintenance

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ABSTRACT OF THE
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The concept of Virtual Operation Center (VOC) for smart maintenance is studied in this research. The goal is to find out applications and structure for VOC in the maintenance of paper, board and pulp manufacturing and the potential benefits it can bring.

Research structure is exploratory multiple case study with five interviews from other industries using VOC applications and six interviews conducted with the main case Efora Ltd's key personnel. Literature review is done on service innovations, operational excellence, Industrial Internet and service operations.

The research shows that several VOC applications have potential to improve maintenance operations making them smarter, leaner and more effective. Applications can also improve network collaboration between maintenance company, its clients and key partners in cooperation profiting all parties. Conclusions are valid in restricted framework of this case study.

Keywords: Smart maintenance, Virtual Operations Center, Industrial Internet, Operational Excellence, Service Innovations

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Diplomityössä tutkitaan Virtuaalisen operointikeskuksen konseptia paperi-, kartonki- ja selluteollisuuden huoltotoiminnassa. Tavoitteena on kartoittaa operointikeskuksen rakennetta ja mahdollisia sovelluksia sekä niiden tuomia potentiaalisia hyötyjä.

Tutkimusmenetelmä on kartoittava monitapaustutkimus, johon kerättiin tutkimusdataa haastatteluilla. Tutkimuksen päätapaus on Efora Oy, josta haastaltiin kuusi avainhenkilöä. Lisäksi haastateltiin muilta toimialoilta viisi yritystä, jotka käyttävät Virtuaalista operointikeskusta vastaavia sovelluksia. Kirjallisuuskatsaus käsittelee palveluinnovaatioita, operational excellenceä, teollista internetiä sekä palveluoperaatioita.

Tutkimus osoittaa että usealla Virtuaalisen operointikeskuksen sovelluksella on potentiaalia parantaa huoltotoimintoja tehden niistä älykkäämpiä, leanimpia sekä tehokkaampia. Sovellukset voivat parantaa myös verkostoyhteistyötä huoltoyhtiön, asiakkaan ja laitetoimittajien kesken hyödyttäen kaikki osapuolia. Tulokset pätevät rajatussa tapaustutkimuksen viitekehyksessä.

Avainsanat: Älykäs kunnossapito, virtuaalinen palveluoperointikeskus, teollinen internet, operational excellence, palveluinnovaatiot

Preface

Writing this thesis was a rewarding job as the subject was interesting and quite unexplored. This gave me free hands to conceptualize and visualize something new. The study gives a strong belief that a well structured Virtual Operation Center with appropriate processes and operation models gives competitive advance in maintenance business. Virtual Operation Center operations model is a good example of potential of Industrial Internet.

I want to thank Adjunct Professor Kirsti Lindberg-Repo for the idea and inspiration for the topic of my thesis, Professor Martti Mäntylä for helping to scope down the subject and to find D.Sc. Jari Collin as my thesis instructor. Special thanks to Jari for inspiring, motivating and encouraging guidance throughout the writing process - best possible guidance one can get!

In the beginning of writing I got very professional guidance from Apramey Dube who was able to show me the right direction when I got lost. As a doctoral student himself, he knew the pain points of writing a thesis and how to get over them.

I want to thank Efora's management group whom I got to get to know while writing the thesis at their office. Thanks belongs also to interviewed personnel for good cooperation at Efora and to the case company representatives.

I got great support from my family, my second family Skipoli, friends and Mr. Lance Westberg who was my co-creator, wrestling with his own thesis at the same time as me.

Helsinki, 10.6.2015

Henri Pohjalainen

Contents

Abbreviations

CBM	Condition based maintence
CMS	Content management system
DCS	Distributed control system
DMS	Document management system
ERP	Enterprise resource planning
GE	General Electrics
II	Industrial Internet
MES	Manufacturing execution system
O&M	Operations and maintenance
OEE	Overall equipment effectiveness
OSC	Operations service center
PDM	Product data management
PLC	Programmable logic control
PLM	Product life-cycle management
Scada	Supervisory control and data acquisition
TQM	Total quality management
VOC	Virtual Operations Center

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1 Introduction

The digitalisation is evolving manufacturing environments across all industries. Increased connectivity, improved data gathering and analysis, cloud computing and personal smart devices offer possibilities to reinvent how work is done. With these new capabilities maintenance companies can help their clients in manufacturing to achieve far greater reliability and higher utilization rate of machines and to improve the life-cycle management of machines. Maintenance companies have a change to broaden their service offering and to grow their business.

Corporate giants like General Electric (GE), Cisco and IBM are investing strongly in Industrial Internet (II). II can be considered as the industrial viewpoint to digitalisation. GE and Cisco have estimated II market to have potential of $14.4 trillion of value (net profit) between the years 2013 and 2022. (Bradley, Barbier, and Handler 2013; Annunziata and Peter C. Evans 2013). The value comes from improved efficiency in production and working and by new business and new service concepts. In April 2014 GE had already pulled in about $800 million in revenue from Industrial Internet related sales growing significantly from the year 2013 (Overfelt 2014).

Benefits of II can be harnessed in two ways: 1. By capturing new value created from technology innovation and 2. By gaining competitive advantage and grabbing market share against other companies less able to transform and capitalize on the II market transition (Bradley, Barbier, and Handler 2013).

"This change will affect all those who work with, service, or maintain industrial equipment, medical devices and other machines: field engineers, aircraft pilots, technicians on oil rigs, doctors and nurses, and many others." (Annunziata and Peter C. Evans 2013) Service and maintenance business is one of the potential winners in the II development. Industrial Internet enables better condition monitoring, improved predictive maintenance through data analysis and new possibilities for fleet management and life-cycle management.

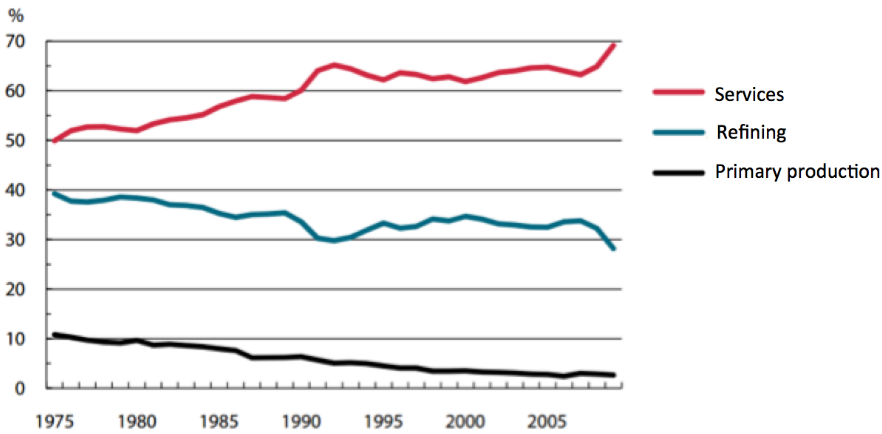

Figure 1: 70% of GDP comes from services

Service business is growing in Finland. Even 70% of the employment comes from service sector and more and more of our industrial companies export is based on services (figure 1). In most of the industrial countries industry's share in gross domestic product is decreasing and share of service is rising (figure 2) (Arantola 2010).

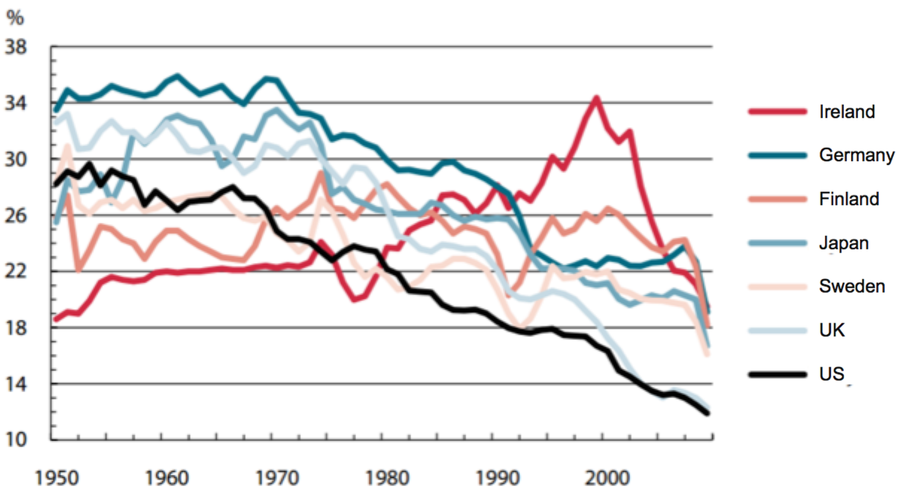

Figure 2: Industry's share of modern countries GDP has been decreasing for a long time

Research organisation Market-Visio has conducted a market situation overview of Finnish Industrial Internet. On the research they estimate that Industrial Internet brings 1,4 mrd euro of new business in Finland until 2020. Despite this considerable opportunity, approximately 70% of Finnish organisations react passively to the possibilities of Industrial Internet. (Nygren and Ahlgren 2014)

It is essential for Finland to stay competitive in services as we cannot compete with cheap workforce or resources or technological superiority. For maintenance services Industrial Internet is without a doubt a key to success and competitiveness.

Taking the foregoing into account the topic of this research is meaningful to Efora Ltd and which is a case company in this study, but also for Finnish national economy.

A Virtual Operations Center (VOC) is in the very center when implementing new II based solutions to maintenance business. Therefore VOC is the focus of the study. The concept of VOC is explained in the next chapter.

1.1 Concept of Virtual Operations Center

Virtual Operations Center is a service platform run in a cloud. Data is gathered to VOC from other systems and processed and refined to valuable information and services. Services and information are available to relevant stakeholders in an appropriate form via the cloud service. VOC acts as a service center providing electronic tools for everyday work. Mobile devices and the cloud service enable location independent use of VOC and real-time information sharing through it. It is a system connecting machines, employees, client sites, site networks and suppliers. One way to simplify the idea of Virtual Operations Center is represented in figure 3.

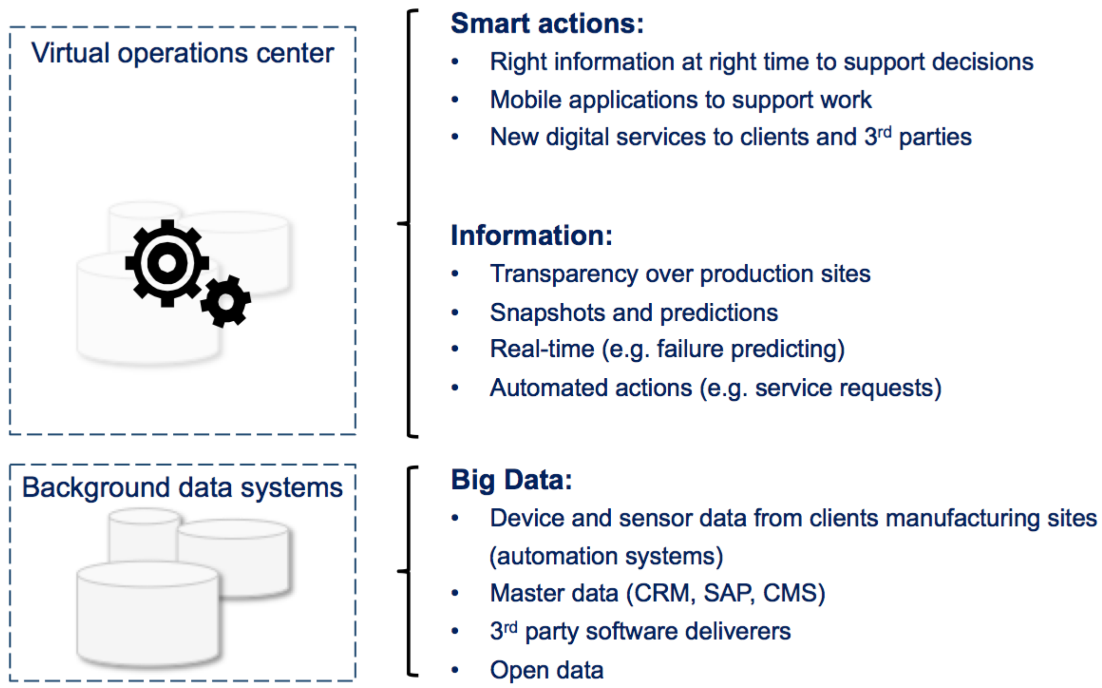

Figure 3: Virtual Operations Center concept

To the maintenance company VOC is a tool to increase client value and improve its own efficiency. VOC enables the maintenance company to improve its clients' life-cycle management over their machines and whole production lines. This is made possible by better data analytics, information sharing and co-operation with machine suppliers.

VOC is a tool for making workers day-to-day work easier. VOC can have different features and dashboard views for different levels of staff depending on their needs. To front end mechanics VOC can enable error reporting with a mobile device, screening automatically updated task list on the screen of a smart phone and checking details of a machine in need of maintenance. It can also show personal dashboards of employees' own performance, rosters and act as a platform for reporting hours and executed tasks.

Virtual Operations Center can also provide performance figures against target metrics on production lines, sites and a whole network for example the utilization rates of employees and machines. It can be used as a tool to improve operations and to plan and schedule maintenance and resources. A Virtual Operations Center can have functionality for predicting unexpected breakdowns by analyzing massive data amounts with machine learning algorithms.

A Virtual Operations Center for maintenance in paper, pulp and board business is not a standardized concept which would exist loads of examples and knowledge. Its functions and capabilities are made possible by digital technology which continuously evolves. The existing knowledge base on Virtual Operations Center can be considered vague. Therefore a holistic view of benefits, capabilities, structure and requirements of VOC is needed and researched in this thesis.

A Virtual Operations Center can improve client value in maintenance through new service innovations and improved operations management, which are made possible by Industrial Internet technology. These three fields are studied as separate wholeness in the literature review, as there is no literature which would offer ready viewpoints of Virtual Operations Center in maintenance business.

1.2 Research problem and questions

The research problem: What new capabilities a Virtual Operation Center can provide to improve efficiency and increase client value for maintenance service operations in Finnish paper, pulp and board industry?

RQ1: Identify best practices and potential benefits that can be achieved with knowledge based decision making and smart actions in maintenance service operations enabled by Virtual Operations Center.

RQ2: How VOC can be used to improve level of automation and the use of shared resources in distributed operations and network collaboration?

1.3 Research process and methodology

Research structure and methods are derived from Robert Yin's famous book Case Study Research and Methods (Yin 2003). Yin describes relevant situations to use different type of research strategies. This research has several special features, which defines the strategy to use. According to Yin a case study is relevant, when the research questions are in form of how and why, study does not require control of behavioral events and it focuses on contemporary events. These matters are fulfilled except the why question. However, identifying the benefits can be considered as an answer to why to implement Virtual Operations Center to daily operations in maintenance.

The lack of ready-made solutions and small amount of earlier studies do not provide a base for making propositions, theoretical statements or conceptual framework. In these cases it is justified to choose exploratory case study method. (Yin 2003) The purpose of the exploration is described by research questions.

Design of the research is a multiple case study. Cases were studied by open ended interviews which were recorded and transcribed and analyzed afterwards. Credentials are listed in table 1. Efora Ltd is the main case and in addition there are five smaller case companies to support the findings from other industries viewpoints.

Efora Ltd is a maintenance company owned by Stora Enso Ltd (SE). Efora is responsible for maintenance in SE's six different pulp, paper and board manufacturing sites. Capabilities and benefits of Virtual Operations Center are screened with open ended case interviews with Efora's key personnel.

Reference cases are used to explore possible capabilities, use cases and benefits of Virtual Operations Center. Another point is to form a benchmark for VOC solutions to identify what is needed to achieve a leading position in Finnish Industrial Internet.

Reference cases in this study are from mineral processing, electricity grip operating, ship power, elevator manufacturing and telecommunications industries. All reference companies have different special features which are relevant for this study.

Mineral processing company has its own technology and solutions to remotely monitor conditions in mines they are operating in. Telecommunication and power grid companies are forerunners in operating and maintaining distributed network of assets and and using digital technology for their advance. Ship power company is using and taking advantage of sensor data from ship power technology implemented in large cargo ships and passenger ships. Elevator manufacturing company has been able to grow their maintenance service business remarkably in the last 15 years and therefore interesting to study.

Research structure is presented in the picture 4. In the first introduction chapter the purpose and importance of the study are justified and the concept of Virtual

Name	Organisation or Industry	Role	Date
Ilkka Tykkyläinen	Efora	CEO	25th of Feb 2015
Tapio Laakso	Efora	Chief Business Development Officer	23rd of Jan 2015
Antti Kymäläinen	Efora Imatra	Development engineer	27th of Jan 2015
Matti Kokkila	Efora Oulu	Development engineer	26th of Jan 2015
Mika Immonen	Efora Uimaharju	Development engineer	13th of Feb 2015
Pertti Kukkola	Efora	Development engineer, life-cycle management	25th of Feb 2015
Reference case 1	Mineral processing	Vice President, Products and Technologies	15th of Dec 2014
Reference case 2	Electricity grid operating	—	18th of Feb 2015
Reference case 3	Ship power	General Manager, Asset Performance and Optimisation, Product Management	19th of Feb 2015
Reference case 4	Telecommunications	Director	16th of Mar 2015
Reference case 5	Elevator & escalator manufacturer	Digitalisation strategy Vice President	10th of April 2015

Table 1: Credentials and interview schedule

Operations Center is clarified shortly. The exploratory research methodology and the credentials of the case study are presented. Data collecting and analysing procedures are also opened up.

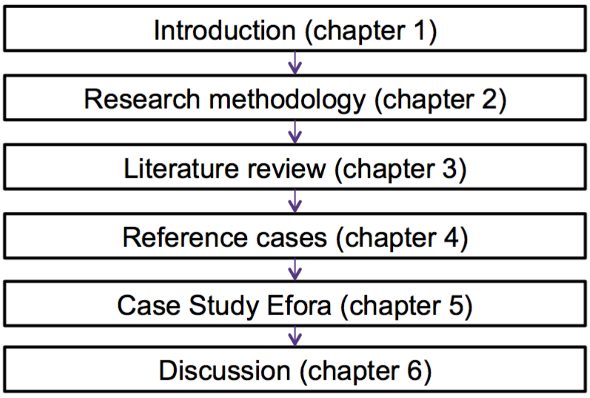

Figure 4: Research structure

Second chapter is the literature review which is divided to three sections: Service innovations, Improving maintenance service operations and Industrial Internet. Two first sections cover developing and improving services and service operations and provide an overview on maintenance service operations and strategies. Third section goes through Industrial Internet effects on maintenance business.

Third chapter is about other industries and what is going on in reference companies regarding to Virtual Operations Center. Main case of this study is handled in fourth chapter.

Thesis ends up with conclusions of reference cases and case Efora in the fifth chapter and discussion in the chapter six about future of Virtual Operations Centers and Industrial Internet and potential further research topics.

2 Literature review

2.1 Service Innovations

To stay competitive in growing services market companies need to pursuit for excellence continuously and improve their offering to match demands of the client. This section handles service innovations research which gives a good viewpoint on improving services and developing new ones.

Service innovations are an effective way to fight commoditisation and gain competitive advantage in the marketplace. New service innovations improve the brand image through better service experiences and improve client retention and new client capturing. Service innovations also improve organizational culture and drives to more efficient business model providing higher growth. (Lindberg-Repo and Dube 2014)

Industrial Internet is a possibility for new service innovations. It can be used to increase operational effectiveness and to grow business with broader or totally new service concepts to old and new clients. The advanced use of technology saves costs on maintenance but equally, it allows the company to personalise the service (Bessant, Lehmann, and Möslein 2014).

2.1.1 Dimensions of service innovations

Hertog represents six key dimensions of service innovations which need to be considered in conceptualizing a Virtual Operation Center. "Every service business has six elements or dimensions that are essential: the service clients, the service concept, the employees and service culture in the service delivery system, the technology and processes as part of the service delivery system and the service business as an integrated system as final dimension." (W. v. d. Aa, Hertog, and Jong n.d.)

From client perspective, service innovations should aim to facilitate improved value creation and more accurately focus on 'value-in-achievement'. This points out that value is realized as a client gets jobs done more successfully and in a better manner (Lindberg-Repo and Dube 2014). In maintenance business this means that new innovations should help client to achieve better reliability of production lines, more effective use of resources and better life-cycle management. Maintenance company is a resource for the client so improving company's efficiency improves client's use of resources.

Client is a co-producer of the service. (Normann 2000) Maintenance in forestry industry is done in deeply integrated collaboration and therefore new service innovations should involve clients as well as the service provider. Thus the interaction process between the provider and the client is an important source of innovation.

Hertog's second dimension is the service concept or offering which is the actual value created to client. New concepts offer value in a new way. Service innovations may be embedded in a tangible product but the innovation itself is often a new idea or concept of how to organise a solution to a problem. Many new service concepts are combinatory as they combine elements of services that do exist individually or as part of other services into a new combination or configuration (W. V. d. Aa and Elfring 2002). Virtual Operations Center combines elements of existing services e.g. reporting and brings them to a new electronic service platform provided as wholeness. Virtual Operations Center also includes new service innovations which have not existed earlier.

Third dimension is the employees and service culture. Appropriate management, organisation and innovative environment are needed to allow service workers to perform their job properly and to develop ways to do their work better. Client can be considered as a part time human resource being a productive factor in the service delivery (Normann 2000). This is very important aspect in forest industry maintenance because of the deep co-operation between the client and maintenance company. Client-centric service innovations help the client to co-create better value for themselves. The client as a co-producer and the design of the client interface are important issues in this innovation dimension.

The fourth dimension is the technological aspects of the service delivery system. There are three different delivery forms, all supported by, but not restricted to technology. First, the new innovation can be an entirely new concept. A good example is Skype, which enabled worldwide Internet calls with affordable price. Second form is an innovative client interface of which smart phone apps are a good example. More and more brands have their own client interaction platforms which companies use to communicate with their clients. Good examples are newspapers, with their news apps and consumer good brands like Nike. Nike+ customer platform is used for two-way communication: to get feedback from clients for crowd sourcing purposes and also for marketing purposes to clients' direction. The third form is a new service delivery method from which Spotify and Netflix are good examples. These companies brought music, tv-series and movies to mobile devices, without the need of picking your cds or dvds from a video rental shop or downloading the whole thing from Internet. A totally new service does not exist in the market yet and an improvement in a service makes an old service somehow better and brings added value to a client. (Lindberg-Repo and Dube 2014)

The fifth dimension is related to new revenue models. To create well-matched and equal revenue sharing models to Industrial Internet application requires considerable ingenuity. Industrial Internet applications uses data gathered from sensors and devices and then analyses the data and uses it to optimize wholeness. Wholeness can be e.g. fleet of machines from single machine vendors or production lines including machines from tens or hundreds of machines vendors or even a fleet of factories. Finding the optimal way to help the client can require co-operation with several actors in the value chain. There is no explicit model for this co-operation and righteous revenue share in it. The question is: if the client gains x% savings or more revenue with better maintenance service, how to share it between the actors in the chain, who all have participated to optimization. If a maintenance company acts as an integrator in the process they can achieve a strong position in the value chain.

The sixth dimension, the integrated business model, combines the five dimensions and brings the innovation to system level. Creating and developing new service innovations can affect to working routines, client interfaces, skills required, ICT applications and business processes. These need to be adjusted accordingly to make sure new service concepts can be realized in practice so that service configurations stay in balance (W. v. d. Aa, Hertog, and Jong n.d.).

2.1.2 Service innovation processes

This chapter presents the environment in which the service innovations are born and also the processes to develop new innovations. Developing processes can be divided to more structured and to ad hoc approaches. Innovations can be categorized to resource based or process based innovations which have different identified success factors.

Environment of developing innovations can be divided to three states. Lowest stage, where least innovations happen is the actual working level where problems are solved with already known solutions. The second level is when the problems occur, and solutions need to be invented, but this is rather problem solving than innovating. The third level where the innovations really happen is when neither the problem nor the solution is known. This require out of the box and cross-discipline thinking and a lot of resources.

Two main streams can be identified in making service innovations. “First approach conceptualizes the service innovation process as structured, systematic, and sequential, while the second views the service innovation process as less formalized and emergent” (Skålen et al. 2014). One systematic approach is New Service Development (NSD) model, which has its roots in New Product Development (NPD) model. NSD consists of a sequence of linear stages. These stages are often ideation (development of a new service idea), idea evaluation, deployment of a deployment team, service blueprinting, prototyping, testing and market launch. In service innovations the first few stages require a large handful of resources: Clients, frontline employees, key account managers, suppliers etc. may have valuable insight for the innovating. Research has proven that frontline employees more often have more implementable ideas than the client yet less innovative and vice versa (Lindberg-Repo and Dube 2014). In this research a vertical sample of employees from a maintenance company’s organization is used to get insight in possible service innovations.

“Another view of service innovation process is characterized by low level of formalization and that they are emergent, unsystematic, and conducted ad hoc as a solution to a particular problem posed by a given client, and integrated with day-to-day operations” (Skålen et al. 2014).

In-situ and ad-hoc problem solving in the field should be communicated up in the organization as explicit knowledge for service innovation as shown in figure 5 (Lindberg-Repo and Dube 2014). Front end service employees sees the client needs and new ways to operate in different way, than the managers who are also in responsible for developing the processes and the way of work. The silent knowledge should move from the field up to the managers, so they can design and improve services. Managers communicate new ways of performing work up to directors (highest level in figure 5) who then decide if new innovations are in accordance with the strategy and if they are profitable.

Ideas and developing the concept goes up in the chain (figure 5) and the decisions and executing force flows top-down the chain. This information chain needs to be transparent and clear to effectively adapt and implement new service innovations. Clear process for innovation creation with transparent development model sets the whole organization to drive services into new higher level.

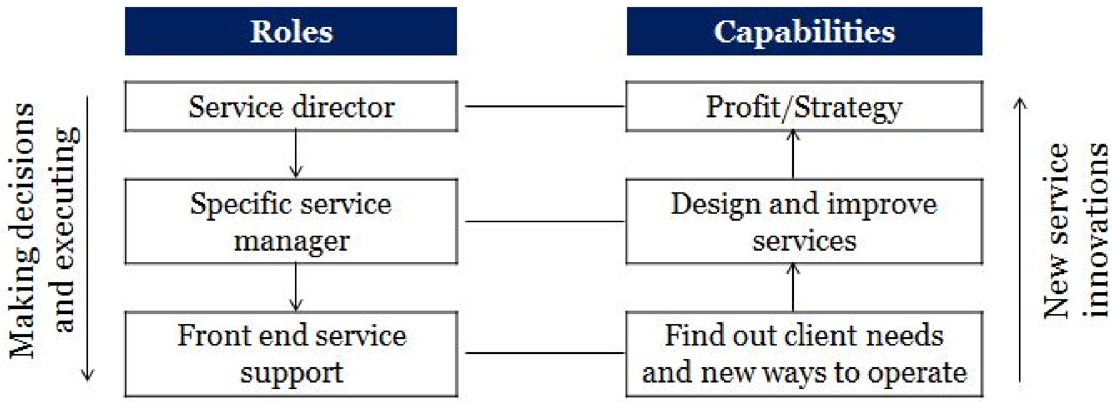

Figure 5: New service innovations development in organization hierarchy

Skålen divides the service innovating into four categories with four variables and provides terminology and success factories for different categories:

1. Adaptation: Existing resources are integrated in new ways in existing practices
2. Resource-based innovation: New resources are integrated in existing practices
3. Practice-based innovation: Existing resources are integrated in new practices
4. Combinative service innovation: New resources are integrated in new practices

In resource-based service innovation processes, the key to success is to acquire and apply the right resources, developing and matching them, and aligning them with client requirements. Thus, managing resource-based service innovation processes may be about acquiring a new technology, developing the knowledge of either the personnel (e.g. HRM) or the clients and knowing what the client wants through marketing research. In practice-based service innovation processes, success factors are managing how the value proposition is communicated, how team-building is conducted, and how problems are identified in the clients' processes. In combinative service innovation processes, managing what value a value proposition promises, as well as how this value is internally facilitated and co-created with the clients, is the key.

2.1.3 Spreading innovations in organisation

According to Chew et al. know-how and innovation transferring in organisation consists of four phases: creation, identification, transfer and application. Creating or innovating new ways of operation can be done centralized or non-centralized. Centralized model would mean for example a team that is responsible for finding new better ways of action. De-centralized way could be that site managers create an atmosphere and environment which stimulates or encourages innovating. (Chew, Bresnahan, and K. Clark 1990)

Identifying innovations requires detailed information exchange, plant-manager meetings and on-site visits. This function requires that central staff can identify outstanding performance from a distance. Proper metrics helps to target the search of best practices to right sites and production lines.

After identifying a new best practice its transfer to other sites needs to be planned. Practice needs to be well defined and its interfaces with all other processes need to be identified. The transfer phase disseminates the created and identified practices to other sites in such a way they can be usefully applied. At the application phase managers and operators need to be willing and able to apply the new innovation to use.

Chew et al. state that meaningful incentives to motivate creation, transfer and application of know-how are difficult to create without measures that identify good performance. Transparency on performance with harmonized metrics could be provided with a Virtual Operations Center.

Clear views on performance against other sites would give an healthy incentive to search improvements on all sites. If the plant managers do not act proactively with on provided performance information then the network manager can demand action. VOC could also provide a communication channel for plant managers. One possible model would be that plant manager sees a comparison dashboard with overall metrics. By clicking on metrics, one would go on more detailed level on factors having an impact to metrics. At some level there would be contact persons with numbers and one could immediately call the person who is responsible for a certain area of excellence.

2.2 Improving maintenance service operations

Service Innovations (section 2.1) were introduced as one way to improve and develop services. Another approach to develop services is to drive operational improvement with methods of operational excellence, performance measuring and benchmarking.

First two subsections gives an overview of maintenance operations and strategies in pulp, paper and board manufacturing. Next three subsections presents performance measuring and benchmarking, knowledge management and organisational learning and the most common operational excellence methods: total quality management (TQM), six sigma and lean thinking. Benchmarking is more suited to continuous development while operational excellence methods aim in longer term, major change. Performance measuring is handled as a necessary part of developing service operations execution and management. (Johnston and G. Clark 2005, p. 416) Total productive maintenance (TPM) is lean thinking from maintenance perspective and therefore chosen to one subject.

2.2.1 Maintenance operations in a paper mill

This chapter introduces basic principles of maintenance service business in paper mills. It gives reader an understanding of both field level maintenance and also managing the maintenance operations. Objectives of maintenance, maintenance strategies, maintenance function and also the basic field level tasks are introduced to the reader.

In paper, cardboard and pulp manufacturing sites and machines are large: A site can be a few square kilometers wide area with tens of different production lines. One production line can be over hundred meters long, ten meters wide and contain tens of thousands devices. Naturally the outputs are also massive and interruptions in production are extremely expensive. The cost of a planned maintenance pause can be forecasted and kept in control but in case of an unexpected malfunction, resources for maintenance need be arranged ad hoc and the break can have unpredictable consequences.

Maintenance management gets its objectives and requirements from business requirements. Requirements are derived from business goals which determine the production objectives, asset strategy, customer satisfaction, safety and environmental issues. The challenges for the mill management are how to ensure profitable, effective, high quality and safe operation. Measurement to fulfill these requirements are operating rate, overall equipment efficiency (OEE), availability of equipment, speed (performance rate), quality rate (saleable production), maintenance costs, other operating costs, investments and major replacements (Leiviskä et al. 2009, pp. 236-244). Maintenance has a direct or indirect effect to all of these measurements.

Typically the maintenance objectives include

1. the definition of the proper level of maintenance, through optimization of the maintenance/production ratio,
2. the economic optimization of global costs (direct maintenance and lack of maintenance),
3. planning and optimization of consumption of resources earmarked for maintenance,
4. optimization of performance (high levels of efficiency),
5. involvement of personnel,
6. improvement of user/customer relations and
7. control and guarantee of the quality of performance.

There are tradeoffs between objectives so maintenance management's task is to find optimum between allocating different resources. One especially important key figure related to paper industry's maintenance is the OEE which combines three measures: availability, performance and quality.

Maintenance function consists of maintenance planning, resources planning and development, management of maintenance processes, execution, follow-up and continuous improvement. Maintenance planning includes long term and short term scheduling of maintenance shutdowns, and shorter breaks. Resource planning and development optimizes the human resources (distribution between using own workforce or using subcontractors) and supply chain management, warehouse levels and sourcing. Executing the field level maintenance tasks is the responsibility of blue collar workforce. Follow up and continuous improvement are keys to make profit and stay competitive. (Leiviskä et al. 2009)

Increasing sophistication of plants, increasing automation level and therefore growing capital costs require high availability for mills to stay competitive. Thus maintenance has an important position to remain and improve effectiveness and competiveness of all manufacturing industries including paper mills.

Maintenance activities have significant impacts on various functions in a manufacturing environment. Effective maintenance lead to optimal maintenance costs and low production costs, high overall equipment effectiveness (OEE) and effective production control, which reinforces the impact of maintenance activities on OEE. OEE itself lead to high net sales and combined with effective production control enables undisturbed production, which guarantees the quality of products. When production goes as planned, raw material and buffer stocks can be maintained in low levels which results to low capital employed. Undisturbed production also leads to prompt and complete deliveries which combined with low production costs and high net sales leads to high margin EBDIT. This and low capital employed translates into a good financial result and high turnover on capital. (Leiviskä et al. 2009)

2.2.2 Maintenance strategies

Figure 6 shows the two categories of maintenance strategies. All three forms of maintenance (condition based, predetermined and corrective) are needed in paper, board and pulp manufacturing. Preventive maintenance is typically more cost-efficient than corrective maintenance and therefore the optimal maintenance strategy.

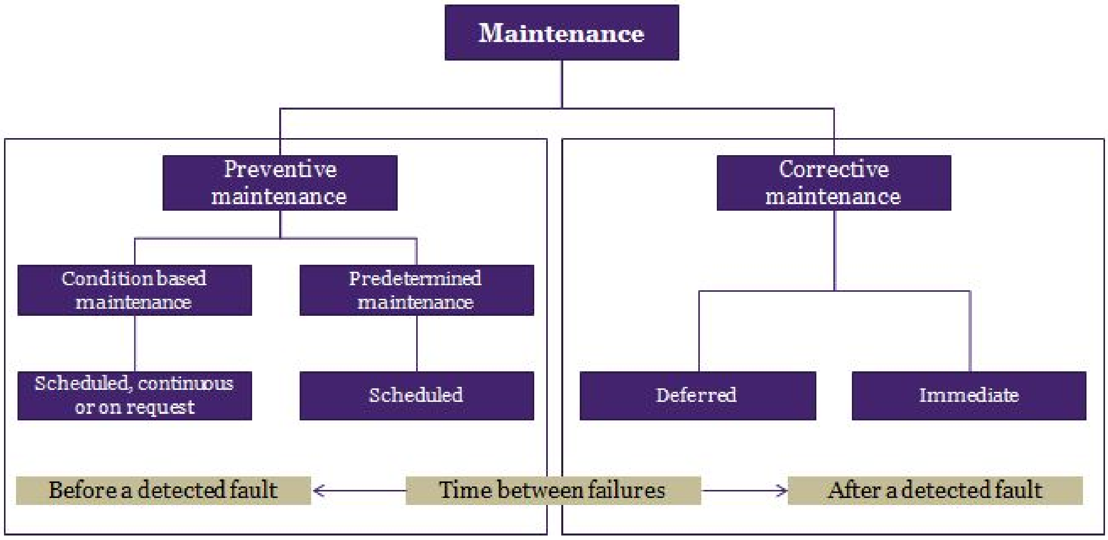

Figure 6: Preventive vs. corrective maintenance (Leiviskä et al. 2009, p. 252)

Condition based maintenance (CBM) is technology that strives to identify incipient faults before they become critical which enables more accurate planning of the preventive maintenance. CBM can be achieved by utilizing complex technical systems or by humans manually monitoring the condition by using their experience. Normally a mixture of both is used. (Bengtsson et al. 2004)

Condition based management is the most cost effective type of maintenance but both corrective and predetermined maintenance are inevitable. Corrective maintenance is the most unwanted category of maintenance as it is unexpected and therefore it has the highest costs. Malfunctions where corrective maintenance is needed can interrupt a whole production line causing problems is production quality and deliveries to customers. If the maintenance resources are not planned right, corrective maintenance can also face resource problems with employees and spare parts.

Running the production in paper mill causes the production environment and process to get dirty, which affects the process' reliability and the quality of products. Therefore predetermined and scheduled breaks are necessary to keep operations running at certain level of quality. Smaller breaks, which can last for example a day can be scheduled long beforehands, but also quite spontaneously if process is detected to go below certain levels on quality or on other measures. Longer integration breaks, which can last few weeks, need to be planned very carefully to optimize time and resource usage.

Condition based maintenance requires continuous monitoring of assets and making forecasts from gathered data. Data is gathered from machines, process and business functions, to optimize and plan the maintenance before machines break and disrupt the production unplanned.

2.2.3 Performance measurement & benchmarking

Performance measurement is done for four good reasons (Johnston and G. Clark 2005, p. 359–360): communication, motivation, control and improvements. Measuring the performance on some area of operation gives a strong signal to employees of that areas importance and that drives employees for better performance. It is also important in means of communicating and implementing new strategy. Measuring performance also motivates employees to achieve their own targets on a particular area. It is important to keep measuring and the support to achieve goals in balance. One key purpose of measuring performance is to have a control on operations. Measuring is the feedback loop of continuously improving processes. Improvements can be achieved by many ways with measuring performance. Often simply communicating a measure is enough for obtaining improvements. By linking measures with rewards can improve performance also.

KPIs to follow can be financial, operational, external or rate of improvement (Johnston and G. Clark 2005, pp. 362–363). Different categories should be balanced right to steer operations into right direction. In example giving weight too much for financial KPIs can harm the operational outcome or vice versa.

A benchmark is a reference point or a target against which performance can be measured. Benchmarking is measuring organisations performance against internal or external target.

Benchmarking can help organisations to

1. Asses how well they are performing
2. Set realistic performance targets
3. Search out new ideas and practices

4. Stimulate creativity and performance innovation
5. Drive improvement through organization

First and second points are the inner circle in the figure 7. This is straight forward measuring and monitoring the performance against target metrics. Defining reasonable metrics can be a difficult task because organisations measure things in different ways. After right things to measure and a base by which performance can be compared is achieved, realistic targets can be set and this loop will possibly lead to improvements through organisation.

Metric benchmarking reveals how organisation is doing against certain metrics, but this will not necessarily tell managers how to improve the processes. The outer circle in figure 7 is important in developing processes. Comparing practices is an attempt to search out new ideas and practices and stimulate creativity and performance innovation. (Johnston and G. Clark 2005, p.374-377)

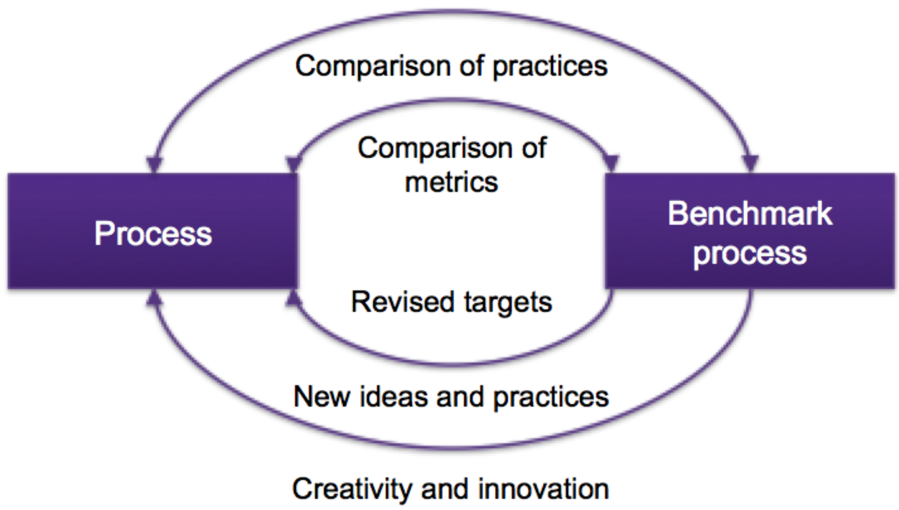

Figure 7: Metric and practice benchmarking

Smith & al. (Smith, Heisler, and Kister 2006, p. 362-363) present generally accepted best practice standards. They have divided benchmarking measures for maintenance to five categories. To some of the standards or benchmarks maintenance have only a partial influence while others might completely dependent on how maintenance is practiced and how well it is performed. Categories of benchmarks are as follows:

1. Preventive/Predictive Maintenance (PM/PdM)

2. Planned & Scheduled Maintenance Work
3. Maintenance Labor (management, effectiveness and optimization)
4. Total plant performance
5. Stores management and budget and cost control

The actual benchmarks and their values are represented in appendix C.

2.2.4 Operational excellence

The focus of Operational Excellence goes toward a long-term change in organizational culture. Total quality management, six sigma and lean are approaches for driving operational improvement and provides frameworks for execution. Concepts are wide and different books offer different viewpoints to subject. If asked from ten people what for example lean is, one probably gets ten different answers. This section provides a short generalized overview of different approaches: TQM, six sigma, lean and TPM.

Total quality management puts client at the heart of quality decisions and improvements (Johnston and G. Clark 2005, p417–418). There is no widespread agreement of what TQM is and what actions it needs from organisation. It is more a management practice than a 'programme'. TQM philosophy is centered on meeting client expectations and to understand which clients organisation wishes to serve and put all effort meeting those needs. Another point of TQM differing it from more traditional quality control is total involvement of organisation. This means creating a culture of continuous improvement which has effect on everyone in the organisation, all working for the purpose of continuous improvement. (Johnston and G. Clark 2005, p417–418) TQM enjoyed widespread attention during the late 1980s and early 1990s before being overshadowed by Lean manufacturing and Six Sigma.

Six sigma is a set of tools and techniques aimed at understanding and improving processes. Six sigma is industry in itself with clearly defined structures and training courses. Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, mainly empirical, statistical methods, and creates a special infrastructure of people within the organization ("Champions", "Black Belts" and "Green Belts") who are experts in these methods.

Six sigma includes different tools for driving improvements and one most favoured tool is DMAIC (Johnston and G. Clark 2005, p418–420). DMAIC consists of five steps:

- Define the business problem
- Measure the current state against desired state
- Analyse the root causes of the business gap
- Improve the process using six sigma tools
- Control the long-term sustainability of the solution

Lean service management presents seven deadly wastes, which should be eliminated from production (Smith and Hawkins 2004, p.9, 108–112). These wastes to avoid are overproduction, waiting, transportation, processing, inventory, motion and defects.

Overproduction in maintenance means too frequent scheduled maintenance. Machine suppliers provide usually their own recommendations for maintenance frequency and if they also offer maintenance service they tend to estimate the frequency too high for higher sales.

Waiting time consists of time employees wait for tasks to do and time of waiting for needed resources (e.g. spare parts and tools) to be available. Motion means movement of workforce, materials or equipment that does not add value and is not necessary for the process or could be eliminated.

Processing means typical maintenance bottlenecks as inefficient work order system, time-consuming reporting forms and inefficient training. Inventory waste means excessive storing costs for too large inventories or bad handled inventory with no necessary spare parts available. Maintenance defects are instances of reworking, redoing and repeatedly repairing items due to failure of root cause analysis.

To improve the actual maintenance processes towards a more efficient direction, flaws or failures need to be found. One efficient way to find flaws is to monitor the KPIs and seven deadly wastes, and when grievances are found, search for better solutions.

Total productive maintenance is not a short-lived, problem-solving, maintenance cost reduction program. It is a process that changes corporate culture and permanently improves and maintains the overall effectiveness of equipment through active involvement of operators and all other members of the organization. TPM requires sponsorship and commitment from top management in order to be effective (McCarthy 2004).

TPM consists of organization-wide efforts to install and make permanent a climate in which an organization continuously improves its ability to deliver high-quality products and services to clients. While there is no widely agreed-upon approach, TPM efforts typically draw heavily on the previously developed tools and techniques of quality control (Smith and Hawkins 2004, p. 55).

Japanese pioneer of Total productive maintenance, Japan Institute of Plant Maintenance (JIPM), has identified the following five critical success factors for delivering benefits from TPM (McCarthy 2004):

- Maximise equipment effectiveness
- Develop a system of productive maintenance for equipment
- Involve all departments that plan, design, use or maintain equipment in implementing TPM
- Actively involve all employees from top management to shopfloor workers
- Promote TPM through motivation management: autonomous small group activities

2.2.5 Knowledge management & organisational learning

A Virtual Operations Center enables efficient knowledge and know-how transferring within organization. Employees of the maintenance company and the client can access relevant information from the VOC cloud service, monitor the current situation of operations, key performance indicators and compare their own performance to other actors' figures. This chapter analyses the possibilities and challenges of knowledge management and organisational learning from Virtual Operations Center point of view.

Research have identified the key processes that drive organizational learning, as well as its context and effects. These processes can be divided into three stages: knowledge creation, knowledge retention, and knowledge transfer.

In a research considering knowledge transfer in distributed manufacturing operations Chew et al (Chew, Bresnahan, and K. Clark 1990), noticed that even plants with relatively similar core technology, products, processes, missions and environments may have significant differences in productivity. Measures between sites were harmonized by removing the effect of independent variables and differences in productivity were tracked down to be caused largely by localized know-how.

Plants need to have similar features and environments in order to improve performance with knowledge transferring between sites. If core technology, products, processes and missions are similar, information sharing can be used to improve the whole network. On the other hand factors that usually inhibit the implementation of knowledge sharing are geographically dispersed and dominant position at market place. In the case of geographical disperse forming reliable metrics to compare sites can be a significantly hard or impossible. Dominant position in a marketplace can drive managers to be satisfied with the current situations and does not provide incentives to improve operations unlike in a highly competitive situation.

Effective information sharing enables spreading local best practices to the whole network. Problem is that information does not flow naturally and it is not standardized. Information may not be quantitative and measured in numbers but processes, attitudes, know-how or procedures. Therefore the model for spreading a local innovation to a network practice must be carefully planned and relevant stakeholders need to be involved in planning.

Benefits of harmonizing best practices and sharing valuable know-how seems obvious but there are four factors which slow down or prevent it from being widely practiced. These factors are culture of the network, measurements, incentives and the role of staff.

Culture of the company influences management's beliefs and values about the nature of production, the character of clients and the sources of high performance. Deceptive beliefs can be summed in three: plants are unique, managers are unique, and best performance can be achieved by matching right manager with right plant. While all plants have unique features, their core business can be strikingly similar. While each manager is a unique individual, certain managerial concepts and skills should be effective in more than one plant. If one believes in plants' and managers' uniqueness then variance in measures and KPIs can be considered normal and this concludes that one site cannot learn from another. Analysis in Chew's research shows that there are many opportunities for transferring know-how in the firm (Chew, Bresnahan, and K. Clark 1990)

Second problem is the performance measurement. Forming a network-wide harmonized performance measurement system is a challenging effort. Usually network managers' focus on profitability, but the most profitable plant does not necessarily have the most productive operations as the environment can have a significant impact on profitability. Therefore environmental impact should be eliminated from the measures and metrics that are equal, transparent and equal to every actor should be conducted. Data for creating a performance measures described can also be hard to get.

Third problem is plant managers' incentives to improve network-wide performance. A compensation system and processes should be created for managers to drive network wide improvement. This would work as a pull incentive for managers to proactively work towards searching and sharing best practices and knowledge. Network managers also need a system for pushing low performing site managers to improve operations and develop service innovations.

Fourth problem is related to recognition of good practices. First step is to find the most productive and efficient plants. The next step would be identifying the best practices which are the roots of good overall performance. This requires experienced staff and vision and understanding of other plants.

2.3 Industrial Internet and smart maintenance

This chapter gives an overview of Industrial Internet and also presents a framework to review its effects on maintenance business. The four part framework is derived from General Electric's creditable article *Industrial Internet: Pushing the boundaries of minds and machines* (Annunziata and Peter C. Evans 2013).

2.3.1 What is Industrial Internet?

The term Industrial Internet was made famous by General Electrics which in its famous article (Peter C Evans and Annunziata 2012) stated II to consist of three elements (figure 8).

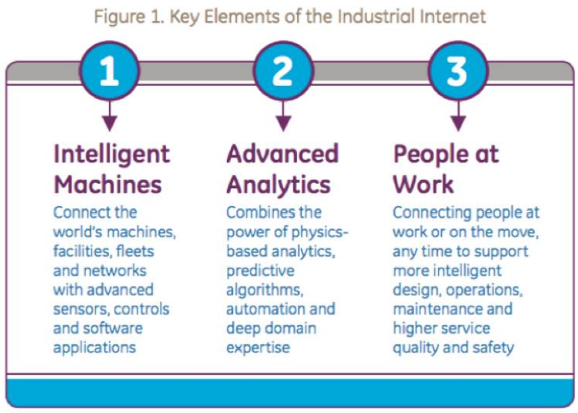

Figure 8: General Electric's perspective on Industrial Internet

First element is intelligent machines and fleets which are networked and combined with advanced sensors, controlling and software. Second element is advanced analytics which combines measuring physical events to analysing them with machine learning algorithms, automation and industry specific knowledge. Third element is empowering people with an interface to the organisations digital environment enabling them to do their work more efficiently and to improve manufacturing process, maintenance, quality and safety.

Blackrock Capital defines Industrial Internet as "The Industrial Internet of Things is connecting the physical world of sensors, devices and machines with the Internet and, by applying deep analytics through software, is turning massive data into powerful new insight and intelligence." (MacDonald and Rockely 2014)

Industrial Internet revolution is happening now as the related technology has achieved sufficient maturity. Computing infrastructure has developed through expanded data storage capabilities, increasing processor performance and evolution of cloud computing and big data tools and advanced analytics including machine learning and other data mining techniques. Communication infrastructure has seen evolution in wireless connections and also in connectivity added directly to small parts of hardware and devices. Introduction of IPv6 Address Scheme also supports the exponentially growing amount of things connected to the internet. Third cornerstone is smart, connected things containing processors, sensors, and software with easy connectivity. (Porter and Heppelmann 2014; Korhonen and Valli 2014)

The gains from Industrial Internet can be divided to evolution, which means developing the ongoing business, to revolution, which means developing totally new business, and to increasing the value of products. The relevant potential for maintenance business in pulp paper and board business are the two first mentioned as maintenance do not have any physical products as their business outcome.

> "Smart processes are capable of intelligent actions and responses. They maximize performance, cost effectiveness, and profit by planning, continuously monitoring status and impacts of responses and applying learning to determine and implement appropriate action for planned and unplanned situations. Actions and decisions are adaptive, predictive and proactive." (Davis et al. 2009)

According to General Electrics intelligent machines, transmitting valuable data, optimizing operations and empowering mechanics are the drivers of change in maintenance business (figure 9). GE's categorisation is used as guidance for dividing this topic to subsections.

Figure 9: Four drivers transforming the way people service and maintain industrial equipment (Annunziata and Peter C. Evans 2013)

Above-mentioned drivers of change are mostly related to increasing operational efficiency. Industrial Internet also enhances life-cycle management of assets. Product's usage history along its life cycle (from cradle to grave) can be used more efficiently for life-cycle management (Camarinha-Matos et al. 2013, p.4–12). This provides maintenance company an opportunity to take bigger role in managing clients assets' and thus capturing more value in the value-chain.

2.3.2 Intelligent machines

A cornerstone of smart maintenance are smart operating assets. Intelligent machines are also a cornerstone that Industrial Internet provides for improving maintenance operations. Davis describes the state of operating assets in smart maintenance as follows:

> "Operating assets – people, plant, equipment, knowledge, models, databases, etc. – are integrated and self-aware (via sensors) of their state. Field devices, actuators and operating equipment have intelligent processing capability with the sensors needed for self-awareness. Every system is able to recognize its condition and publish that information so it, and all other interoperating devices can take immediate and appropriate action." (Davis et al. 2009)

Intelligent machines improve machine to machine and person to machine connections leading to more intelligent design of machines and greater control of instrumentation and production conditions.

On current situation quality control and condition monitoring rely on human perception and dexterity. Intelligent machines can help workers in these tasks with automated condition monitoring and analysis. Sensors on machines can stream on-line data to centralized servers or cloud. Analyzing this data and providing it through cloud platform to technicians helps workers to improve quality of process and maintenance.

"As proactive operations, smart manufacturing incorporates real-time data sensing to eliminate failure before it happens, to the extent possible." (Davis et al. 2009) Data from intelligent machines can be used to create real-time failure forecasting models. Failure forecasting enables preventative maintenance and reduces unplanned downtime.

Greater connectedness of machine fleets enable also more comprehensive and adaptive control of the process, but it is more of an interest of operations than maintenance. (Scholze, Barata, and Kotte 2013)

A maintenance company, which gathers or has an access to client company's data has a big opportunity in data usage for life-cycle management. The data can be analyzed to provide fact based information on machines performance, failure frequency and maintenance costs and thereafter be used to support investment decisions.

If compared to machine suppliers, which quite regularly gather or are interested in collecting data from their own machines, a maintenance company has access to the big picture with data from the process and from all the machines. With the data gathered from whole length of production line, machine efficiency and costs can be analyzed and used as information base to support investment decisions.

Life-cycle costs of a single machine consist of three parts timely. First part is the procurement phase which capital costs happen only once. After this phase is the useful life of the system in which the machine is operational and in use. Labor using the machines, energy and maintenance are costs involved in this phase. Last phase is the decommissioning when the machine comes to the end of its life-cycle and needs to be removed or replaced.

According to Fedele approximately 60% of the total life cycle costs can be imputed to its useful life, the period when client uses the product (Fedele 2011, p.21–24). Figure 10 shows the significance of new investments to the overall life-cycle costs. Timely investments are essential to optimise costs of the whole life-cycle.

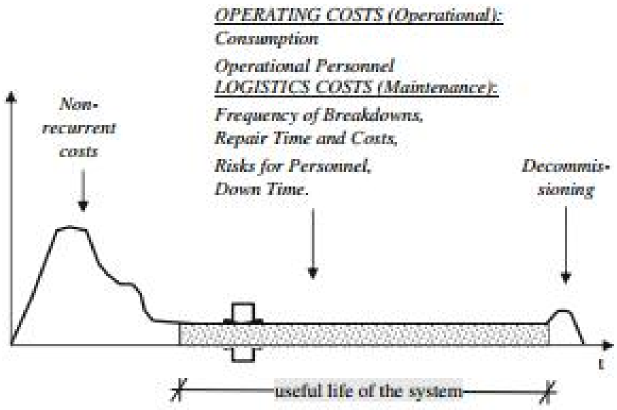

Figure 10: Life-cycle costs divided to three phases and two categories (Fedele 2011)

Operating costs tend to decrease when the level of automation increases. Maintenance costs consists of the labor costs, material costs, spare part storing costs, engineering support, contractors and overheads. Failed operations or failed service cause down times which leads to production or quality losses.

Providing transparency on operational and maintenance costs with the Virtual Operations Center lines could help managers to find problems in production lines and allocate resources to reduce costs in problem areas. Managers could use the information to identify the need for investments due to increased operating and maintenance costs.

2.3.3 Transmitting valuable data and information

"Smart processes have all pertinent information available, accessible and understandable to the parties or functions that need the information. All needed information is available when it is needed, where it is needed and in the form in which it is most useful." (Davis et al. 2009)

Sharing useful and valuable information to different shareholders is one key mission of Virtual Operations Center. Data gathered from maintenance company's operational environment contains significant potential to be processed into valuable information and refined to more intelligent processes and decision making.

Remote monitoring and operation management is necessary in operations and maintenance (O&M) of an asset network that is wide and distributed. In manufacturing environment monitoring and controlling is confined to the physical assets much more concrete. Normally factories and power plants have control rooms, where operators can monitor conditions and status of operations.

In the Industrial Internet era monitoring becomes more effective, as the amount of sensors increase and storing and analyzing data becomes cheaper and more efficient. For example smart grid technologies have taken advantage of new technology and thus been able to increase reliability, resiliency and efficiency (Falahati, Fu, and Mousavi 2013, p.1087–1095). Monitoring helps to detect and forecast failures and respond rapidly or pro-actively and it can also be used as a guide for optimal control.

There are three key stakeholders who can benefit from information mined from big data. Firstly all the improvements should aim to a increase maintenance company's clients' production reliability and performance. Secondly the maintenance company can improve its effectiveness in various ways by Virtual Operations Center. Third party to get benefits from is suppliers. With gathered data turned to information maintenance company can provide knowledge to suppliers about how their machines are performing in particular production environment.

Valuable data can be gathered from four different sources shown in figure 11.

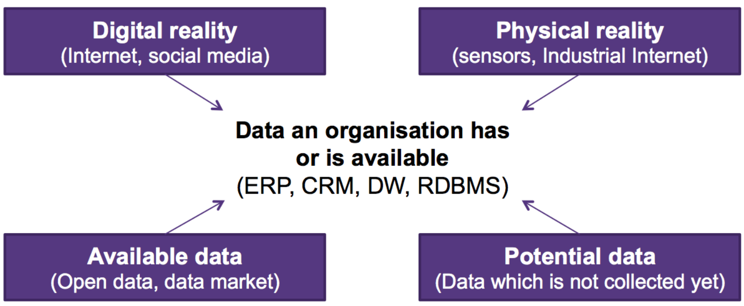

Figure 11: Sources of Big Data

Data can be used for forecasts, monitoring and snapshot views of present situation and for history reports. Forecasts can be made of machine failures, demand of maintenance work and spare parts. Data can also be used to monitor assets and processes in real-time. Snapshot views gives the viewer an overview of current situation of planned maintenance work, maintenance work in progress and utilization rates of workforce. History reports show the performance on given time period for further analysing and continuous improvement.

Increasing data amounts and new capabilities to analyze the data and capture value from it raises the value of data. Data ownership needs to be defined in systems where several stakeholders gather, store and use the data.

Justifiable owners of the data in manufacturing environment could be the device suppliers, manufacturing company which owns the assets or the companies (if separate from mentioned) which are operating the data gathering and storing. Any combination of this is also possible, and the data rights can be shared. Rights need to clarify who owns the data in the last resort, who can use it and exactly how and for what purposes.

2.3.4 Optimizing operations

Operations centers engage in data segmentation and filtering for customized "fleet" views, historical analysis, real-time analysis and forecasting. Optimizing operations is what intelligent machines and better data management is needed for.

In certain situations maintenance company can have the best overview on machine fleets. In these cases maintenance company can take a role as an integrator between client and machine suppliers to help client maximize the life-cycle value of assets. Value for client is better reliability and optimized maintenance and investment costs. Value for machine suppliers comes from data they get from of their machines.

Suppliers can use the data for further production development and they can point out to areas where suppliers need to make investments. Suppliers can also help clients by analysing how their machines are driven and then giving guidance to users.

Providing transparency to the manufacturing, maintenance and supply chain with VOC and Industrial Internet can eliminate different stakeholders maximizing only their own profits. This could create a business model where different actors team up to maximize client value together with cooperating as a team. Companies which products and designs have the greatest impact on total system performance will be in the best position to drive this process and capture disproportionate value (Porter and Heppelmann 2014).

Better planning of resources is made possible by better forecasts for maintenance needs combined with integrated planning of production scheduling and maintenance breaks/shutdown. Forecasts are created for months ahead to allocate sufficient resources in a long run. Forecasts for few weeks ahead are made to plan optimal level of maintenance capacity. The most detailed forecasting is made by the means of big data analysis. With big data and machine learning one can forecast upcoming breakdowns of machines before they happen and get the problem probably fixed before.

Reliable forecasts enable efficient capacity planning. Service capacity is defined as the maximum level of value-added activity over a period of time that the service can consistently achieve under normal operation conditions (Johnston and G. Clark 2005, p.277).

Reliable forecasts on a longer time period enables using of shared resources between sites. Maintenance people might have special skills and knowledge which are needed in rare occasions. Maintenance people with special skills could be used more effectively by mobilizing them to move between sites according to demand for their special skills. If maintenance needs could also be forecasted more accurately, the mobilizing could be done efficiently so that moving between sites would not strain employees unbearably.

Historical analysis is also important for long term service improving and performance measuring. These views are in both maintenance company's and clients' interest. Real-time analysis is a tool for leading daily operations.

Warehouse management should be done corporate-wide and be monitored efficiently. Inventory is one of the Lean management's seven deadly wastes that should be eliminated. Inventory levels and circulation speed of the materials needed by actual manufacturing process could also be attached to the VOC.

2.3.5 Empowering technicians

"Although intelligent automation is a vital component of the smart process environment, the human resource is essential. In the smart environment, human resources (people) are knowledgeable, well-trained, empowered, connected (via cyber tools) and able to adapt/improve the system's performance. Smart systems recognize the limitations of automation. They provide information and analyses to trained operators and managers who use human experience to determine and bring about the needed action." (Davis et al. 2009)

A virtual platform empowers workers with providing information to enable right decisions actions at right time and with electronic tools to make everyday work easier. Giving workers all data needed for the work via Virtual platform, for example an automatically updated and on-date task list, increases self-directed and proactive working approach.

Proactive employees do not need orders from their supervisors to decide right maintenance tasks to execute at a time. Task list could be prioritized to several categories and within a category employee could choose the work-order. This would eliminate non-value-adding work phases and waiting and also increase the feeling of autonomy on employees.

Empowering technicians with digital applications helps finding lean way of work in means of eliminating waiting, transportation, processing and motion.

> "Knowledge-enabled personnel coupled with knowledge-rich tools and systems are innovating, planning, designing, building, operating, maintaining, supporting and managing facilities in significantly improved ways." (Davis et al. 2009)

3 Reference cases

Four Finnish companies were screened with open-ended interviews and one with more informal company excursion. Purpose of the interviews was to identify best practices and potential benefits that can be achieved with knowledge based decision making and smart actions in maintenance service operations. Second purpose was to evaluate technologies of the forerunner companies, think of possible platforms and technologies that enable the developing of Virtual Operations Center. Third target was to evaluate what is the level of exploiting Industrial Internet in Finnish companies.

3.1 Case 1 - mineral processing

First reference case is a Finnish company aimed at providing technologies and services for the metal and mineral processing industries. Their solutions vary from technology and O&M to planning and delivering a whole production plant. In year 2013 it had over 4000 employee, revenue over 1 500 MEUR and delivered projects in 80 countries. The case is relevant for this research due to company's solutions for leading distributed operations and remote monitoring in mining and mineral processing.

The vice president of products and technologies was interviewed for the study. The interviewee has worked in current business for four years first as the head of services product center, then as the vice president of Minerals Processing Services and latest as the Vice President of Products and Technologies. He also has background for working 9 years in paper business so he can be considered to have reliable insight on the subject.

Case company's remote monitoring system was originally created for the needs of O&M business. Sufficiency of experts and risk premiums in O&M contracts were the triggers to develop remote monitoring and operating systems. When the degree of O&M projects started increasing there was a concern on sufficiency of certain special skills and knowledge inside the organization to cover all projects.

Management level personnel and certain types of operators can be recruited locally but very specialized expertise for minerals processing is not available in common ground. This expertise is needed especially in the starting phase of operations when the process is still unstable and production usually encounters unexpected problems.

Another reason for building the remote monitoring system was O&M agreements which includes certain risk premiums. Contracts for running O&M include agreements on limits in which the process needs to run. Therefore company needs transparency through the process, not only real-time but also as an extensive database on history events.

Big difference between paper production and mineral processing is the automation layers. "Isa-95 standard is used in mineral processing, which gives its own challenges for building any remote monitoring applications, especially if one does not get to start to build the whole automation system from a green field. It is very challenging to build a monitoring system from brown field, because of many different layers in the system. In the distributed control system (DCS) layer there can already be multiple different system provides like Siemens, ABB and Alan Bradley."

According to interviewee, building an effective monitoring system to brown field would require more plug in readiness than is possible in mineral processing. The data should be able to be captured, parceled and transferred in reasonable way. Distributed and complicated automation layers in mineral processing are consequence of three quite isolated process phases. If compared to paper production, the paper machine is a very dominant part of the process. Thus the company providing the paper machine has been able to dominate the automation delivery.

Company's Operating Service Center (OSC) is not a standardized product but instead evolving all the time and different stages of it is installed and in use in different clients. OSC can monitor the whole process flow of mineral processing and it is based on their virtual experience platform. It can also detect faults or changes (also in long period) in process or in machines and deliver the information location independently to the monitoring software. When anomalies are detected in the OSC, the maintenance tasks can be remotely activated on the site via email or telephone.

Interviewee considers earning model as the most challenging part in developing OSC. The most obvious value of OSC is the efficiency of company's own operations. For the clients it is the quick response and quality and transparency of the process. How to make revenue out of SOC or the big data remains still unanswered. One option is benefit sharing but it is troublesome to prove the real effect of OSC on the production output.

Interviewee predicts that a major change in the monitoring software can be brought in by the standardisation and open architecture II systems. "Turning point is when the system changes from multiple closed systems and layers to open architecture or if some player starts to rule the field." (Case interview) He also predicts that II is going to have the biggest influence on sales and marketing, using simulations in operations and product development, optimizing operations, cloud and new innovations.

3.2 Case 2 - ship power

Second reference case is a Finnish corporation which manufactures and services power sources and other equipment and provides services in the marine and energy markets. As of 2013 the company employed over 18 000 workers in more than 70 countries. Company's core businesses are power plants, ship power and services offered to both markets. The use of sensor data to improve services offered to client is what makes the case interesting.

A Product Manager on Asset Performance Optimisation was interviewed on 19th of February 2015 for this study. Interviewee has relevant experience on the topic for over ten years. At the time of interview he was responsible for the digital solutions and services in maintenance.

Company's services are divided to three categories: 1. Condition Based Maintenance, 2. Performance optimization and 3. Remote services. The benefits gained from these solutions are best available performance from the sites, proactive and reactive maintenance and greater cost efficiency.

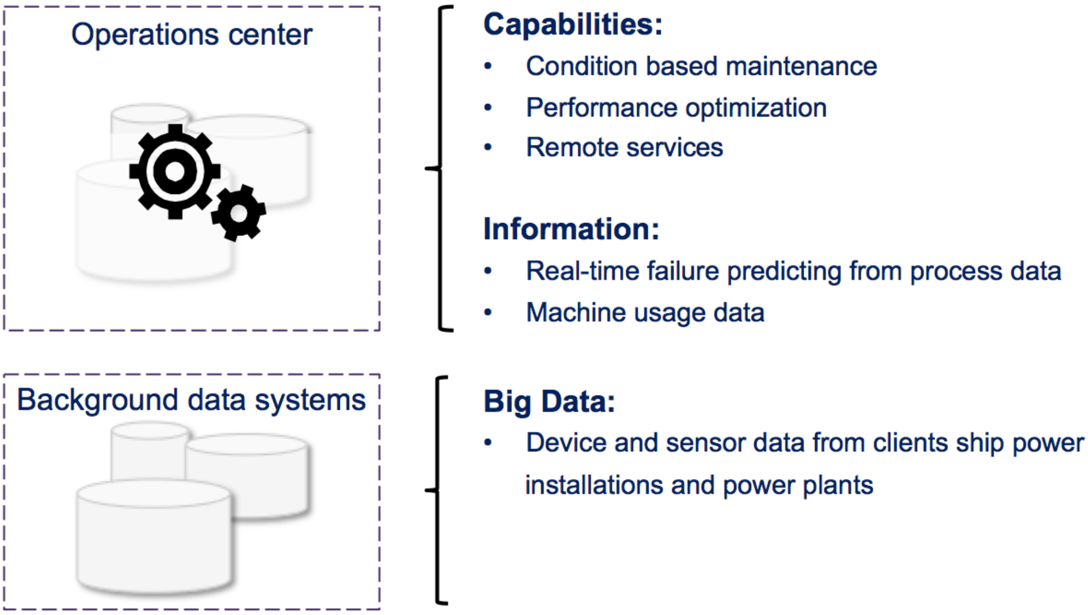

Figure 12: Operation center from ship power and power plants point of view

The company has a condition based monitoring service with a physical service operations center that monitors 200 sites and installations. These sites and installations stream their sensor data to be analyzed by workers in operation center. Workers analyse the data and information they get in the condition based maintenance service and can then point out maintenance need for clients. Technicians in the field send pictures and videos of moving parts in daily basis to operation center and they are used to support analysis.

CBM solutions forecast the upcoming failures in some probability and time period and hence the maintenance can be executed before the failure happens. This functionality is in the center of Industrial Internet benefits for maintenance business.

In power plants the case company is usually running the operations and maintenance. Thus they are also responsible for scheduling and executing the maintenance. In ships the ship's own technicians can handle the maintenance tasks or make a service request to the case company. Condition based monitoring helps in adapting changing situations. "If some part is normally changed between 20 000 hours, but we notice that it will last only 17 000, the client can react to the information we provide." (case interview) Other use cases of CBM data is to support root cause analysis and product development.

Company can also remote monitor the usage of ship power technology and give guidance on the usage to clients as service. "We can give recommendations like use two engine instead of four, or if someone is driving 110% with one engine, we can guide to use two engines with 90% power. I know cases in which we have guided clients to optimal use." (case interview) Client benefits as reduced fuel consumption and longer life of the motors, machines and other technology. This can also be extended to fleet management which handles multiple ships as one wholeness. This way ships can be benchmarked against each other and share the best practices on maintenance and engine cost-effectiveness.

A new application is being built and piloted which gives client real-time views on the power plants and ships. This is partly the same application as company's operation center, but it is offered to client to its own use. Some power plants are already monitored with real time process data which streamed to operation center. Yet all the controlling and running the process needs to be done on the spot. Pilot is aiming to also automate the service requests derived from the data analysis and forecasted failures.

Contracts and models of the data ownership between company and its clients is still under evaluation. Baseline is that the process and machine data is owned by the client who owns the assets. The model of optimising end-customers benefit with a group of operators and suppliers includes complex group dynamics and differing motives. "Winning model is the openness in sharing the data and using open-interfaces." (case interview)

3.3 Case 3 - telecommunications

Third reference case is a Finnish telecommunications company. It offers telephone and broadband subscriptions and entertainment package deals to companies and consumers. It also operates its own telephone and broadband networks. As the end of 2013 it had over 4 000 employees. Company has a modern Virtal Service Operations Center to monitor the availability of services and conditions of the network. Therefore it is a very relevant reference case for this study.

A Vice President of Service assurance and Mobile networks services was interviewed on 16th of March 2015 for this study. At the time of the interview he was responsible for company's mobile networks, and services including building new networks in Finland and other countries, operating and maintaining them and also operations that upkeep the services in all areas. Interviewee has relevant experience on the topic for over ten years.

Case company's virtual operation center monitors conditions of the physical network and also the services running in the network. Services are important to handle as a separate wholeness. Even though the network is up and running, some server which runs for example a text messaging service might be down. Company has been able to provide new digital services to clients based on virtual operations center solutions.

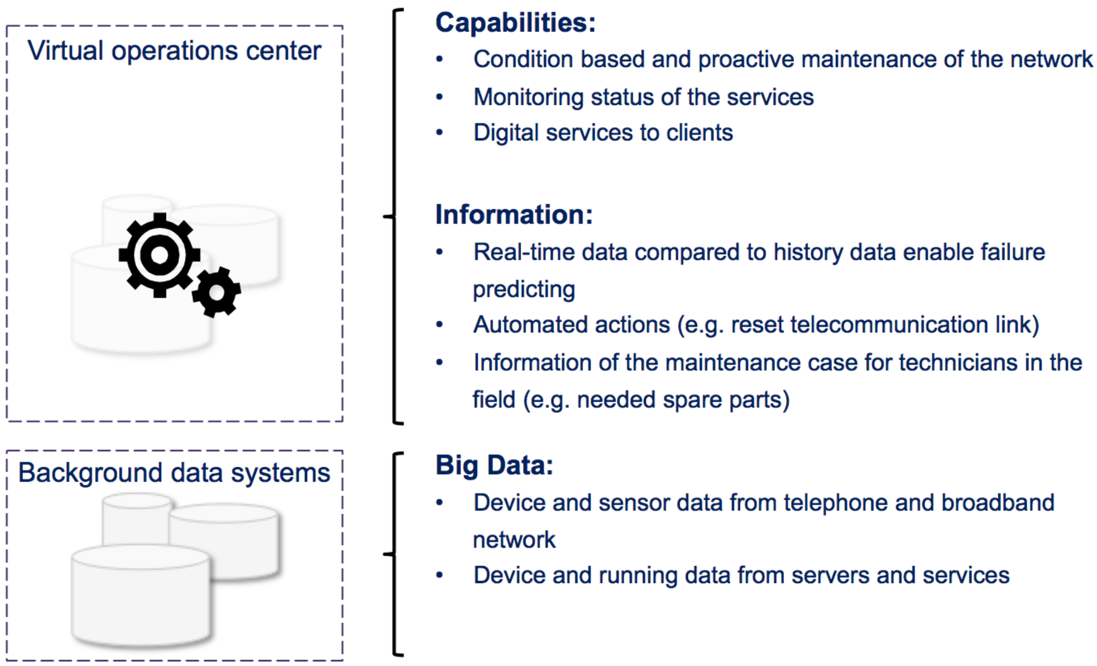

Figure 13: Virtual operation center in telecommunications case

Case company's VOC makes automated notifications of errors in the network or services. The notifications lead to automated service requests or manual procedure to handle the case. VOC is able to predict upcoming failures by comparing the real-time running data to a whole year average and detecting anomalies in it. Anomalies can be caused for example by code bugs or network link getting jammed. The proactive maintenance and corrective actions have risen from 0% to 40% due to the VOC applications. Mean-time between failures have also been increased with more proactive maintenance.

VOC is operated by case company itself for its own purposes but it is also offered to clients as an additional service or an independent service. "For example if we sell network solution to a client we can also sell network management and supervising service in addition." (case interview) In this model VOC is not used only to manage the offered networking services but it can manage client's own local area network. This has been tested e.g. in food industry client whom case company was able to provide valuable information of their call centers' activity distribution and other similar cases.

VOC increases service usability, reliability and quality which are the basic features that support the core business. Less the failures and problems in network and services less the calls for the case company's service desk. Additional or external services on top of the basic services are how the business can be grown with the existing key clients. Third part of new business possibilities are new fields of industry where company's VOC operations model would fit. "VOC operations model have been piloted in fuel distribution — it is surprisingly easy to take control and manage the payment transactions and the functioning of fuel pump. Data and information are relatively easy to capture. The problem is what to do with this information as the industry expertise is not that strong in new businesses."

Virtual operation center can also serve as an information platform for technicians in the field. Information of the maintenance work (needed spare parts and information on the broken machine) can be offered via VOC.

3.4 Case 4 - power grid operator

Fourth reference case is a Finnish power grid operator. Its responsibility is to plan the usage of the main electricity network and also to supervise, maintain and develop it. Fourth reference case was studied as more informal company excursion to a partner company which provides the power grid operator assistance in supervising and monitoring the network.

Case company uses remote video monitoring and control room monitor recording services offered by the partner company. Service includes the hardware installation, including cameras and video recording adapter, and a cloud service to monitor the videos.

The solution is built to visualise situations and replace eyes with cameras in places we need vision on. Good examples of where this can be very useful are remote places or hazardous places. Monitoring can be done for condition monitoring and also to detect motion in undesired places. Remotely assisted repairing can be done with helmet cameras worn by technicians in the field. Video monitoring also has applications on spare part warehouses to monitor the availability and amount of certain spare parts.

Recording the control room screens can be done with a simple adapter inserted to the screen. Video on the screen can then be analysed for example to detect dead indicators that a human will not necessarily notice while sitting in front of the screen. Video can also be recorded to improve operations after failure situation. Recordings can be used in root cause analysis or to make a simulated training case of the situation.

Remote video monitoring and the screen recording can be controlled with control signal received straight from the automation system. This way the recording does not need to be on all the time.

3.5 Case 5 - elevator & escalator manufacturer

Fifth reference case is a Finnish elevator and escalator manufacturer. Company has worldwide operations including new equipment manufacturing and services. Company has grown its maintenance service business to cover 32% of the overall sales. They have a strong effort on developing a winning digitalisation strategy. Therefore company is highly interesting reference company for this study.

A former senior vice president of Development department was interviewed for this study. Interviewee is responsible for Kone's digitalisation strategy and vision which is part of service business development. She has worked for company over five years as a CIO and prior that she made a 12 years career in Nokia where her responsibilities varied across logistics, eBusiness, strategy and quality management. Her core expertise is in the areas of logistics, supply chain management and IT.

Reference company has their own service operations centers built for customer service and maintenance needs. Besides their operations center this case is interesting due to their service business. The company uses big data to optimize people flow in built environment to achieve biggest possible moving capacity to escalators and elevators and to help asset owners for example in marketing purposes.

Company's service centers are centralized (one in one country) and they have a traditional phone services but also more modern tools to support customers and their own field technicians. Another service center solution exists to support financial management and HR and IT. These are also based on human resources, but virtual in a sense that they are cloud services. Country level operation centers use remote monitoring software to analyze the fleets and upcoming maintenance needs. Remote monitoring is based on daily or more frequent data impulses from elevators. When analysis predicts or detects immediate maintenance needs technicians are sent to fix the problem.

Interviewee believes in organisational learning and benchmarking as a tool to develop organisation in an efficient way. Operations center can be used to get a transparent view through global organisation to increase organisational learning and development. In development function it can be used to make ad hoc analysis of certain situations. In implementing new products the operations center software speeds up the feed-back loop which saves cost in logistics and quality management.

Interviewee sees big data as a possible source for new services. The company uses people flow data (data of how people masses move inside a building) to optimize and control the flow. This is useful in big built infrastructure like airports and shopping centers. People flow data is used to to optimize the movement of elevators, escalators and automates doors. For example when an airplane land to the airport and unload passengers to a certain port escalators' moving direction can be changed to optimize escalator capacity to wanted direction.

Dynamic controlling of people flow in big built-up environment requires combining building usage data from the infrastructure owner to elevator company's own data and optimizing models. This is a typical co-operation model in Industrial Internet era. Elevator company needs to think of how to get customers interested to optimize their own assets and they are already offering people flow intelligence service. Elevators are just one part of a building and it remains to be seen what kind of consortiums will be formed to optimize the wholeness. Companys' role would probably be a part of this kind of consortium. Interviewee sees that the silos (lightning, energy, people flow, air conditioning etc) in built environment are slightly slowing down the development of Industrial Internet solutions.

People flow data is also used to plan campaigns in shopping centers to guide people to walk next to certain shops or certain route by changing the movement directions of escalators. They have also piloted models where the marketing-wise optimization would happen in real-time. Clients are also offered different type of reports and analysing software about how the machines are functioning and how does the people flow look like from this point of view.

Data has not yet reached a position where it would be sold as an own product package but instead it is usually a part of bigger service contract and definitely valuable. Interviewee believes that their data can be sold as an own product in the future, but probably not in some years still. Other matters the big data is used are product development, project planning (history analysis and simulations), marketing to customers (product quality and proving the achievable savings) and safety related solutions.

Interviewee provided valuable insight on the change management needed in implementing virtual operations center and new operation models. Main points considered finding a reasonable scope, execute the project till the end and disclose the old operations models after new ones are implemented. Interviewee has seen many transformation projects and how they are left not completed resulting to "worst of both worlds" situation.

Most important success factors are first to finalize the project with strong change management, quickly enough and to the whole organisation. Second point is to scope the project to a reasonable size and to find the few most important things to implement from tens of potential ones. Trying to invent the whole world at once leads to problems. Third point is to analyze new processes' effects and benefits and to take care every step to achieve them is made in the end. For example if new software replaces someones job then the person needs to be moved to other tasks. Fourth point is to ensure the quality with right metrics.

3.6 Summary of reference cases

Possibilities of Industrial Internet have been recognized in all five reference companies. Companies have their own solutions for example to detect predictive maintenance needs, lead distributed operations, use sensor data to optimize operations and to create new services based on continuously developing digital technology.

Predictive maintenance increases reliability and customer satisfaction in mineral processing operations, telecommunications network and elevator and escalator services. Remote monitoring enables use of scarce resources like special expertise in distributed operations like a network of mineral processing plants, ship fleet and elevator services. It also enables the monitoring of hostile environments adding eyes to places where people cannot actively make observations. Sensor data is used for product development and quality management in mineral processing and ship power technology and elevator manufacturing.

Virtual Operations Centers are used to gather and provide data and information for different stakeholders. This helps technicians in the field doing the actual maintenance work and also the management personnel to get valuable real-time analysis of current situation. Technicians get the necessary information of the machines in need of maintenance and can even get real-time instruction from specialists while working in the destination. Management gets a transparency through a whole organisation to make ad hoc analyses of situations enabling right and timely decisions.

Companies are driving research and development work to harness full potential of II. Yet a conclusion can be drawn that holistic exploiting of Industrial Internet is still in its infancy as is the Industrial Internet technology itself. To achieve a forerunner position the time to act is now.

4 Case Efora

> "Companies whose products and designs have the greatest impact on total system performance will be in the best position to drive this process and capture disproportionate value." (Porter and Heppelmann 2014)

The main case of this study is Efora Ltd, which is a maintenance company owned by Stora Enso Ltd (SE). Case was studied by 6 interviews with Efora's key personnel: CEO, Chief Business Development Officer, Development engineer and three project managers in Efora's smart maintenance pilot project. Interviews were conducted in January and February 2015. Interviews were recorded with laptop computer or cell phone and analyzed afterwards.

Efora is responsible for maintenance in SE's six different pulp, paper and board manufacturing sites. Efora's revenue was 189 m EUR and it had 850 employees in the year 2014. (Efora 2015) Approximately 30 percent of the employees is white collar or clerical worker and the rest are mechanics. The average age of mechanics is near 50 years and due to a long experience in the field the expertise of mechanics is very high in the fields of electrical automation and mechanics, which are the basic requirements for successful maintenance work.

The work on floor level can be divided to running the manufacturing operations, which is mostly done by Stora Enso's employees, and doing the maintenance, which is mostly done by Efora's mechanics. The maintenance work can be divided to categories of predictive, preventive and reactive. The predictive maintenance means planning the needs and resources on a long time scale. Yearly plan consists of two longer shut downs, when a whole site is being maintained in a few weeks period. Preventive maintenance means monitoring the conditions and maintaining machines during normal operations and scheduling and planning shorter breaks before unexpected breakdowns. These shorter break last normally one day. Reactive maintenance is needed when machines break down unexpectedly.

During a shut down all production lines, power station etc are fixed, cleaned and maintained. This requires tens or hundreds of external work force and very detailed planning. During a shorter maintenance break as many tasks as possible are executed in a priority order. Shorter maintenance breaks are normally on one production line at a time and can be scheduled beforehand, but in a case of an unexpected breakdown breaks can be carried out rather spontaneously. Normally shorter planned maintenance breaks are executed once a month.

4.1 Overview of Efora Smart maintenance

Efora has a new smart maintenance strategy which is divided to four parts shown in figure 14. Strengthened capabilities in information management is the base for other key strategies.

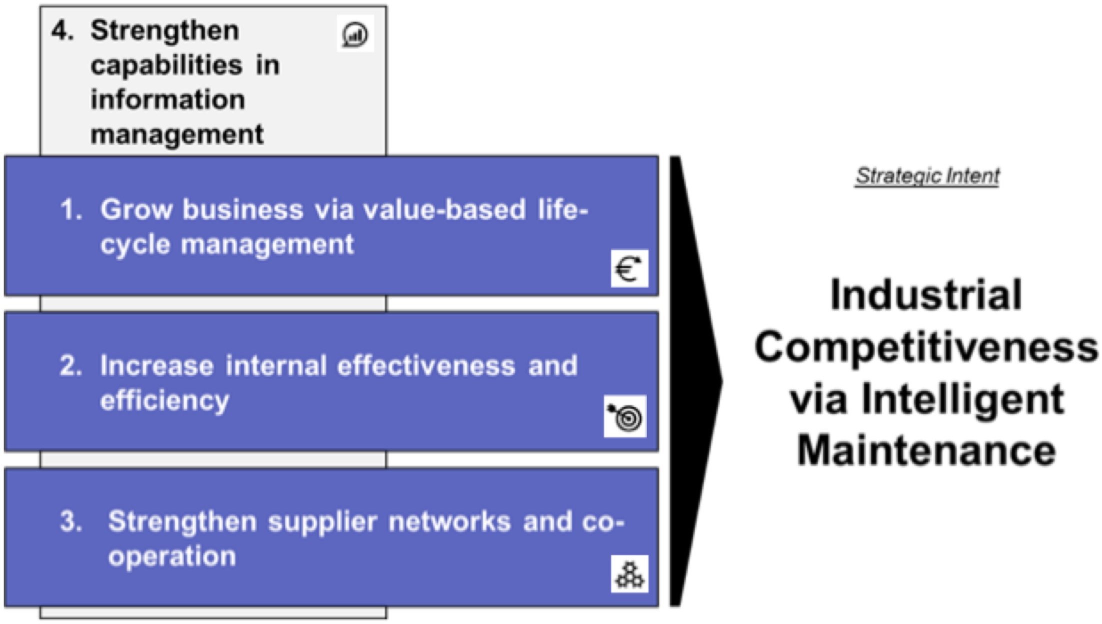

Figure 14: Efora's smart maintenance strategy

Efora has started a pilot project to launch the new strategy. New capabilities are tested in three different production lines (board, paper and pulp) located in different sites. Targets of pilot project are 1. to create and test new capabilities in limited production environment, 2. to improve the performance of maintenance in the pilot production lines and 3. to establish new virtual "Efora Service Factory" way of working.

The key performance indicators to measure success are downtime in hours, planning accuracy (%), overall equipment efficiency (%) and the usage of online channel (%).

New "Efora Service Factory" way of working refers to Efora's own Virtual Operation Center and the processes, information systems and knowledge around it.

Added connectivity via Internet, wireless networks, data analytics, cloud computing and mobility open up new possibilities for Efora to innovate how the maintenance tasks are operated and planned. Virtual Operation Center is a digital platform in the very center of "Efora Service Factory" operations model.

4.2 Virtual Operations Center concept and structure

This chapter presents structure of the Virtual Operations Center concept and its relations to other IT systems in Efora's operational environment. VOC is a virtual platform that bounds together different aspects of Industrial Internet to improve Efora's effectiveness, increase customer value and add new ways of collaboration with client, suppliers and third parties.

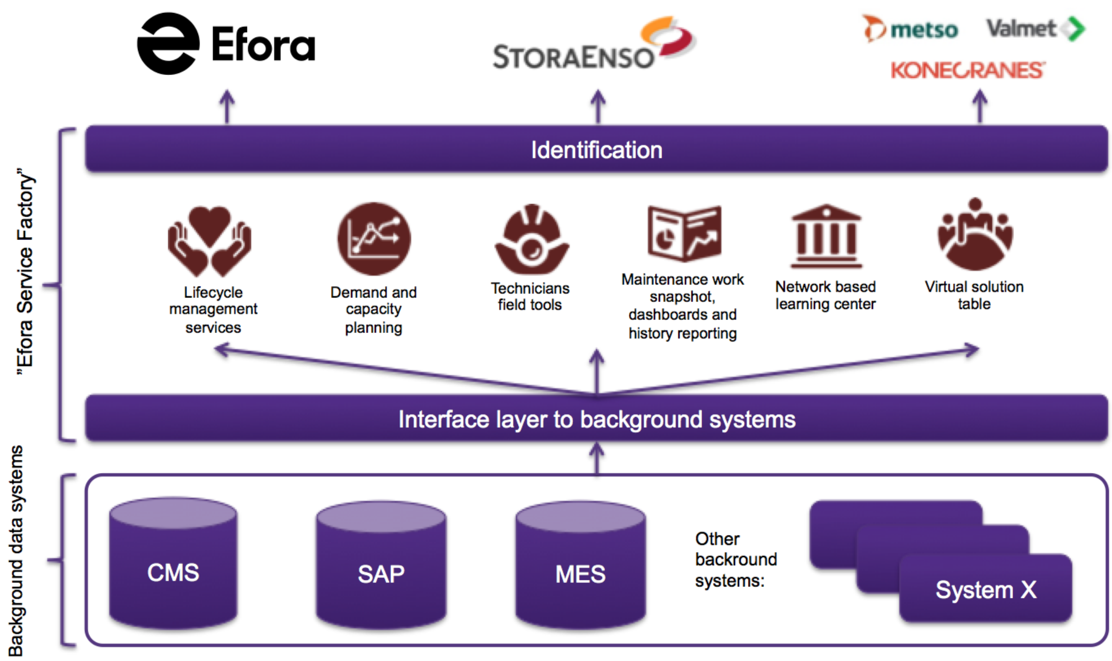

Figure 15: Efora Service Factory is an additional value layer built on top of other systems

Virtual Operations Center provides tools for knowledge supported ways of working, information sharing and communication. Its users are employees of Efora, Stora Enso, suppliers and other third parties. At the moment Efora's daily planning, communication and operations use various systems for different purposes. Virtual Operations Center is supposed to gather different functionalities to one wholeness (e.g. communications, easy task follow-up, managing and reporting, forecasting and continuous follow-up).

Virtual Operations center also has an important role as Efora's own data system. Efora's data functions are integrated to Stora Enso's data systems but they do not have a real Efora's data system. This kind of operating model is quite normal for maintenance since it is a support function for production. Therefore a Virtual Operations Center, maintenance company's own information system, can be a differentiating feature and raise the status of the company. (A. Kymäläinen, personal communication, January 27, 2015)

The smartness of maintenance can be improved greatly with Virtual Operations Center's applications. Applications can provide necessary information to support decision making in the field level operations and for prioritizing tasks for example. One way of information flow is from systems to users and other way is from users to systems. The latter are fault notifications and reporting executed tasks which are now done in SAP. Enabling data flow from users to systems to be done with mobile devices reduces waste on worthless movement.

The Virtual Operations Center is not supposed to replace all the current systems but to utilize the existing systems and compile in one system and one form different functionalities and to also create new ones. This is visualised in figure 15. Many of its planned features are related to information handling and sharing. For example the maintenance planning is still done in SAP but the VOC can provide relevant information to support the planning. Another example is reporting maintenance notifications and executed tasks which still needs to be done in SAP, but the Virtual Operations Center can provide new interface for performing these tasks with mobile device in a standardized way.

Manufacturing environment sets certain requirements and restriction for the information architecture of the Virtual Operations Center. Information security, existing systems (ERP, MES, systems of other suppliers) and physical restrictions for information transfer needs to be considered when building Virtual Operations Center.

One main improvement of Virtual Operations Center concept is to create more controlled and automated data handling processes and to make information easily available for different shareholders. Efora has access to vast amount of data including process data from automation systems including orders, deliveries and resourcing and Efora's own service production data. Data can be in electronic format, but there is also information such as user manuals and instructions for machines in physical files and folders.

Industrial Internet can be harnessed to gain more value from the complex network of systems in paper mill. Network consists of five system levels which are shown in figure 16. First level is Enterprise Resource Management (ERP) system that is used to manage the business information and human resources information. On second level are the manufacturing execution systems (MES) that are plant networks and used for mill management. MES system providers are actors like Metso, Honeywell and ABB. Third level is the automation systems which handles process control and management level. Automation system level gathers data from sensors and actuators via field bus and sensor bus. Data is used in distributed control systems (DCS) and programmable logic controllers (PLC) which then controls the field devices.

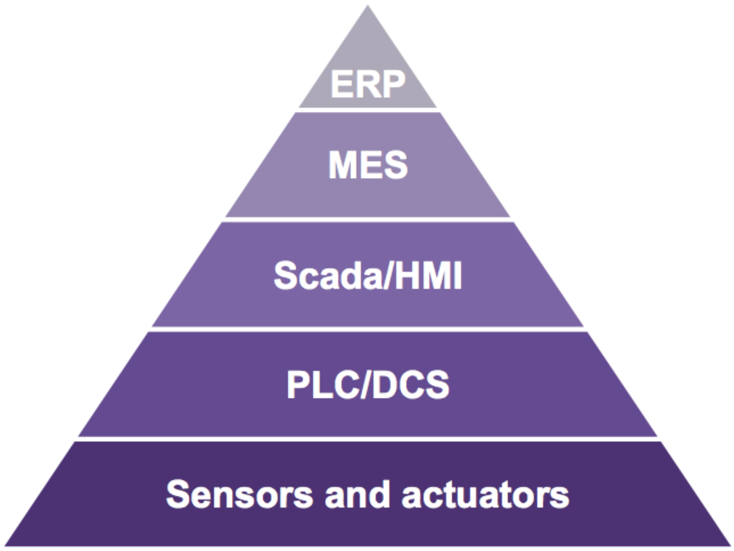

Figure 16: Automation information levels

Industrial Internet's system levels can be divided to operative platforms (ERP, MES, PDM/PLM, DMS/CMS and other operative systems), generic data managing platforms (IBM, SAP, SAS), industrial data analytics platforms (GE, Rockwell

Automation, Schneider Electric, ABB) and non-industrial platforms (Axeda, Eurotech Ltd, Xively). Industrial Internet applications can be built aside existing systems using the necessary parts of existing systems with suitable integration and data transferring layers. II applications should provide new value with combining field expertise and innovative uses of data, connectivity and mobility for new purposes and operating models

The data gathering and storing needs to be planned from the needs of VOC and also with eyes open for expanding use cases of data. Data needs to be well structured and consistent. Polling frequency affects the amount of data and therefore the costs of storing. Data storing can be done internally, or outsourced to another company but the safety of data transfer and storing needs to be verified.

Data analytics give requirements for the data quality, polling frequency and data's availability. Information security again sets requirements for the analytics: where it can be done, how is the information transferred both ways.

Information sharing is highly security related matter. To get any benefit from data and analytics, the information needs to be effectively shared to relevant stakeholders. Reports, dashboards, forecasts, KPIs and other business critical information needs to be transferred from where the analysis is made, to wherever the stakeholders are. Supplier collaboration also requires knowledge transfer in two directions. Data transfer needs to be secured and ensured the information and data cannot leak to outsiders in any conditions.

For factory's information network, it is fundamental for security that there is no entrance to network for outside connections. Demilitarized zone in the network is a logical or physical subnetwork, which is built between company's own local network area and outside facing data systems which are connected to untrusted networks.

4.3 Virtual Operations Center capabilities

Virtual Operations Center capabilities were identified through case interviews. Capabilities and applications are divided to six different categories in Efora's Virtual Operations Center, which has a worktitle "Service Factory" (figure 17). This chapter provides reader an overview on these categories.

Figure 17: Efora "Service Factory" illustrative view on a smart phone screen

4.3.1 Production life-cycle services

Virtual Operations Center provides a common interface for Efora, client and suppliers to manage machines and producation lines life-cycle. In the network collaboration lays an opportunity to grow Efora's life-cycle management business. This is an example of how Industrial Internet can help in creating new service models and deepen the maintenance company's role in client's business. Timely investments to renew or replace the machines before they become a major problem which improves life-cycle management. This affects to target metrics by reducing the interruption hours and by increasing OEE.

"In current customership this would consider the whole business including both major and minor renewals and optimizing operational expenditure and capital expenditure and performance." (I. Tykkyläinen, personal communication, February 25, 2015)

VOC should bring a strong fact-base to support the investment decisions by analyzing the data of machines' failure rates, down times caused loss and maintenance costs. Figure 18 gives a simplified example of supporting the investement decision with facts. If VOC can provide reliable data on possible savings of investment, it makes prioritising investments and making the decision easier.

500 kEUR investment opportunity on a machine		
	Case 1	**Case 2**
Fact base	250kEUR yearly savings due to reduced maintenance and better reliability	50kEUR yearly savings due to reduced maintenance and better reliability
Repayment	2 years repayment period	10 years repayment period
Decision based to rules set by business	Make investment	Current state is optimal, do not invest

Figure 18: Fact based investment decision

Efora and Stora Enso manages investments with an investment backlog. At present state investment backlog has swollen to a size which is hard to manage. Backlog contains hundreds of items and prioritizing the backlog is mostly handwork. Thus the prioritising is not done very systematically. Investment analyses are made in Excel and prioritising is affected by those who "shouts loudest" i.e. those who demands hardest (P. Kukkola, personal communication, February 25, 2015).

Investment decisions can be improved by using effectively the available data and making automated analyses. Analyses are then delivered by Virtual Operations Center so they are easily available for whomever needs them. VOC enables right investment decision at right time increasing Life-cycle profit of machines and production lines.

Prioritisation needs to be transparent so one can inspect in more detail the parameters affecting the prioritisation. By clicking an item on prioritized investment backlog one would get the supporting analyses, which would contain the exact information why the item is critical. A backlog overview over different production lines and sites enables high level resource planning and concentrated project procurement.

VOC also provides common interface to Efora, customer and machine suppliers for managing the backlog. Managing tasks are adding items to the backlog, inspecting the backlog and managing it the sense of setting status to items, removing items and adding additional information to items. This would make the managing easier, more organised and consistent.

In addition to backlog management VOC provides platform and tools for further analyses of machines and production lines overall. An example view of a certain section in a production line could show machine-hierarchy with relevant KPIs. The machines could then be arranged by failure rates or maintenance time and then dug deeper to find a single machine as a root cause for that section's bad performance.

Using suppliers expertise is also necessary in life-cycle management. Life-cycle management platform would be communication channel to suppliers. This way they could more efficiently participate in optimizing the life-cycle costs and losses and use their experience on investment and renewal needs. Suppliers could have a view on their own machine fleet and make suggestions on investment backlog based on their analysis.

Suppliers should also be challenged more on how have they plan the life-cycle and reliability of their machines. If data analysis show machine performance is not on the level supplier promise or has planned, then the problem can be solved together with client and suppliers. Point is to make supplier more responsibility for the life-cycle management of their own machines. (T. Laakso, personal communication, January 23, 2015)

"Machine suppliers' recommended maintenance intervals can be challenged by reliability analysis. In less critical areas the maintenance frequency or quality can be deliberately reduced and so the optimal interval searched iteratively. In more critical areas sensoring can be added to to prevent failure in search for optimal interval and in less critical areas even run to failure is an option." (I. Tykkyläinen, personal communication, February 25, 2015)

4.3.2 Demand supply forecasting and planning

Virtual Operations Center's forecasting features enhance Efora's resource planning. This means optimizing workforce and spare part capacity. By advanced analytics the spare part demand can be forecasted (figure 19) and the inventory levels thus optimized with real-time control. Supply of standard and bulk spare parts with high rotation can even be automatized with data systems provided by 3rd parties. Performance of the forecasting models can easily be analysed by comparing history analysis and forecasts. Providing overall view on warehouses on country level can help optimize the warehousing and spare parts supply on higher level.

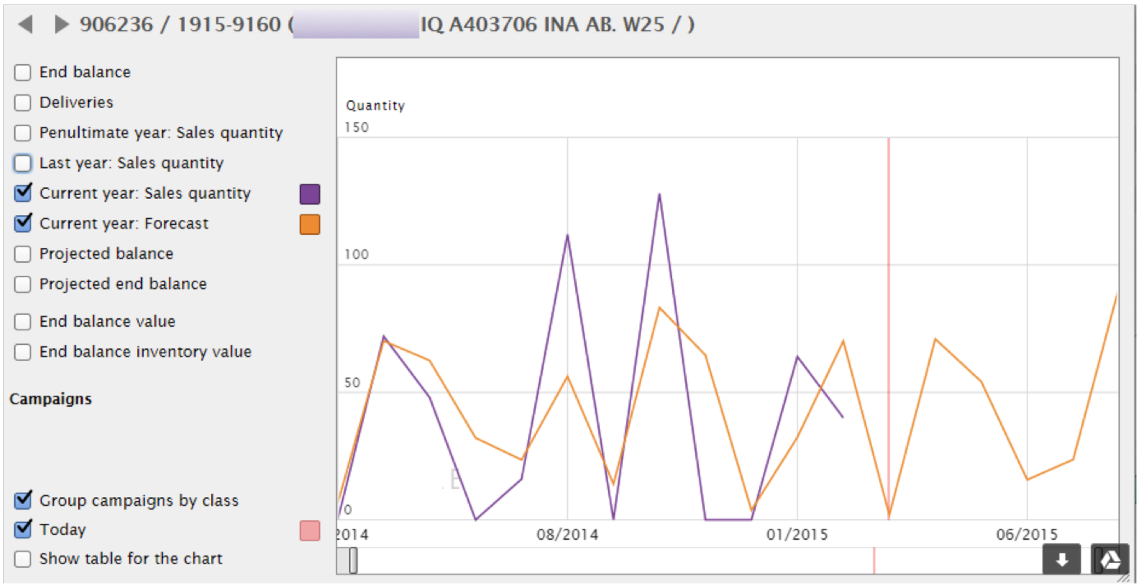

Figure 19: Sparepart forecast vs demand

On current situation the maintenance works demand forecast is limited to SAP maintenance work order book. This view is only few weeks long and it does not contain forecasting at all. Systematic forecasting of maintencane need and spare parts demand needs to be improved. If Efora is extending to other clients than Stora Enso, forecasting capability becomes more and more important.

With analytics provided by 3rd party the work demand can be forecasted to a time period from few weeks to few months. These forecasts can then be used to support maintenance capacity planning made by other dedicated system

4.3.3 Notifications and orders

The current problem is that employees need to move back and forth from production line to machines when they do fault notifications. Walking to a computer to make a fault notification can take more time than the actual repair. In these cases the mechanics do not necessarily make a notification at all. The problem in not making a notification is that important data of maintenance activity and history is lost. To keep the maintenance history data consistent and reliable all the faults should be notified and recorded in the data system.

Because employees want to eliminate the worthless movement they do the fault notifications concentrated. They gather notes to their notebooks while they are at the production line and observe flaws and then enter all notifications to ERP at the same time for example at the end of the week. Possible unclear notes and memory errors cause inaccurate data. Entering notifications is also done hastier as the notebook may contain many notes to do and therefore the focus decreases.

The foregoing problems can be eliminated with electronic application to make notifications and orders in the Virtual Operations Center. With the application both Stora Enso's and Efora's employees can make fault notifications with mobile devices as mobile phone or tablet. This eliminates the waste movement and lowers the threshold of making notification of small tasks. Notifications and orders application can also improve the quality and consistency of gathered data by requiring certain information on every fault note. Another useful feature in the application is adding pictures to the fault notification. Pictures illustrate the problem and shows concrete where the problem is and what it is like.

Reporting executed tasks is also done in ERP and it shares the same problem of waste movement as making the fault notification. Making the notifications and reporting executed work needs to be easy and effortless. A mobile application to handle all this work is essential for increasing efficiency.

There is plenty of information that can be brought within arm's reach through the VOC applications. All machine special data and information, like use instructions, maintenance instructions, maintenance and use history can be checked with mobile device by searching the machine by its unique code. This lowers the threshold to do maintenance tasks of unfamiliar machines and increases capabilities of both the operators and technicians. This information is available via both, the electronic field tools and from the eLearning application (chapter 4.3.5).

The source data needs to be consistent for automated reports. In manual compiling, consistency can be ensured while reports are made. Consistency can be promoted with Virtual Operations Center's reporting tools, which require users to fill in certain information when reporting task execution and working hours for example. (I. Tykkyläinen, personal communication, February 25, 2015)

4.3.4 Real-time dashboard

Sites have their own varying processes for gathering, creating and sharing reports for follow-up, control and development. Reports can be taken from SAP in ready usable form, but others require manual work in combining different data sets, making sure the data is consistent and then making the analyses. This work is typically done in Excel for example once a month for monthly reporting.

Monthly compiled Excel reports lack the real-time guiding and controlling element. Reports provide the client information on how well the maintenance have performed on certain time period and are valuable in making "what could have been done better" analysis. Still the monthly reporting lack a snapshot view on present situation and cannot be used to steer the operations in real time. Current report compiling process also cause manual work which could be eliminated by standardized and automated processes

SE does not have an access to Efora's maintenance service production data, which they consider as a big problem (M. Immonen, personal communication, February 13, 2015). Snapshot views of current maintenance work status and work in progress would benefit the client and Efora in planning and controlling the work. Efora could get the needed reports that the client demands straight from the Virtual Operations Center in which the reports would have automatically produced and the client itself could also see the same reports instantly from VOC.

Snapshot views of present situation would have the guiding element on planning and executing the work. These features emerged as desired and necessary in interviews with Efora's project managers.

The source data needs to be consistent for automated reports. In manual compiling consistency can be ensured while reports are made. Consistency can be promoted with Virtual Operations Center's reporting tools, which require users to fill in certain information when reporting task execution and working hours for example. (T. Laakso, personal communication, January 23, 2015)

Real-time dashboards can be used for organisational learning and improving through benchmarking. Benchmarking is a useful and efficient way to measure own actions and compare them to others. Benchmarking shows unquestionably how own units perform compared to other units inside own network or other units of different organizations. Benchmarks need to be designed so that they are reliable and comparing is reasonable. The key performance indicators need to be harmonized to get comparable results between different sites.

4.3.5 eLearning

An important functionality for VOC would be a learning environment to support the use and maintenance of machines. At the moment documents and user and maintenance manuals are in various formats (folders, papers, electronic documents, words, PDFs) in different places. A virtual learning environment could be an information source where all necessary documents and instructions would be gathered. Building the environment in cloud would make it location independent tool available via mobile devices. Learning environment could also work as a platform to arrange time-, location and machine supplier independent training to Efora's employees. (T. Laakso, personal communication, January 23, 2015)

Learning environment could broaden the capabilities of SE's operators to do maintenance work which they would now need Efora's resources. On the other hand the virtual learning environment could also lower Efora's own employees to do tasks they are not so familiar with, instead of calling in another specialist.

Another point is to teach Efora's employees the process knowledge, to support their work. Storas operators do not necessarily have technical background and Efora's people can have vague knowledge of the process. Knowing the process better could improve maintenance when people understand better the reasons of malfunctions and how the process should work.

Tacit knowledge is one risk that Efora is aware of. eLearning application could be built to manage tacit knowledge with a standardized process. It could for example tried to be passed on with extra trainings or apprenticeship contracts.

4.3.6 Virtual solution desk

Virtual solution desk is a collaboration platform between Efora, client and machine suppliers. Solution desk can be used to analyze and solve problems and failure situations. Machine suppliers get views of their machine fleet performance on client's operational environment via solution desk and failure analysis cases can be taken easily to desk for root cause analysis.

A root cause analysis is made of every failure case to learn from them and to prevent similar cases from happening again. Root cause analysis is made basicly by getting a suitable group together and going through the circumstances of a failure. VOC could provide the facts related to case easily available for the roundtable. These facts would be the failure notification including possible pictures taken of the failure case, history of machine's running data before failure, repairing history etc. Virtual solution desk would provide this information to all parties invited to solve the current problem. This could mean people from client (operators, production managers), from Efora (technicians, maintenance engineers) and experts from machine suppliers. Data could be used in online meetings arranged through VOC solution desk or other online conference application.

Solution desk could be used for remote guidance for maintenance work. Video could be streamed from head cameras while a tecnician is making a repair work in the factory floor. This video could then be watched on other sites in real-time and experts in other locations could guide the technician through a call. This makes the distributed expertise better available to all sites.

Virtual solution desk could have an physical using point in sites, which would contain computers and high level virtual conference capabilities including webcams and screens. This would make Virtual Operation Center in overall more concrete. One could sign to his/her own VOC account in the physical center and get access to same applications as in mobile version.

Machine suppliers have their own applications which are similar to the idea of solution desk. Machine suppliers have the best expertise on their own machines and this resource is needed to run and maintain machines in optimal way. Efora has tested a 3rd party's solution desk successfully but the system can be considered quite basic.

Efora needs their own solution table for two reasons. Firstly they do not want to use different applications with different suppliers. Secondly they can provide client necessary views with one application instead of fifteen different views provided by suppliers. This creates evident value for the client.

"Being part of the Efora's solution desk should be a desired position for the suppliers." (T. Laakso, personal communication, January 23, 2015)

Machine supplier gets a huge value of real-time data and view of their machine fleet in client's operational environment. "Giving a holistic view for the supplier of their machines can teach their designers as much as Efora's people. Machines are not necessarily planned as reliability as the first priority. It is just the best possible technical solution." (T. Laakso, personal communication, January 23, 2015) Data can be used for product development and they can also give guidance on how to use machines or equipment better.

Collaboration between Efora, client and suppliers happens via Efora's VOC. Suppliers should have incentive to participate, because it is their machine and their brand after all which is on solution desk under investigation. Supplier can definitely use the data to improve sales and marketing. (I. Tykkyläinen, personal communication, February 25, 2015)

Kraljic matrix (figure 20) can be used in assessing potential supplier partners to attend the new collaboration models. With strategic suppliers there is least choice and they are the most wanted collaborators due to their importance to SE and also because they are hard or impossible to replace.

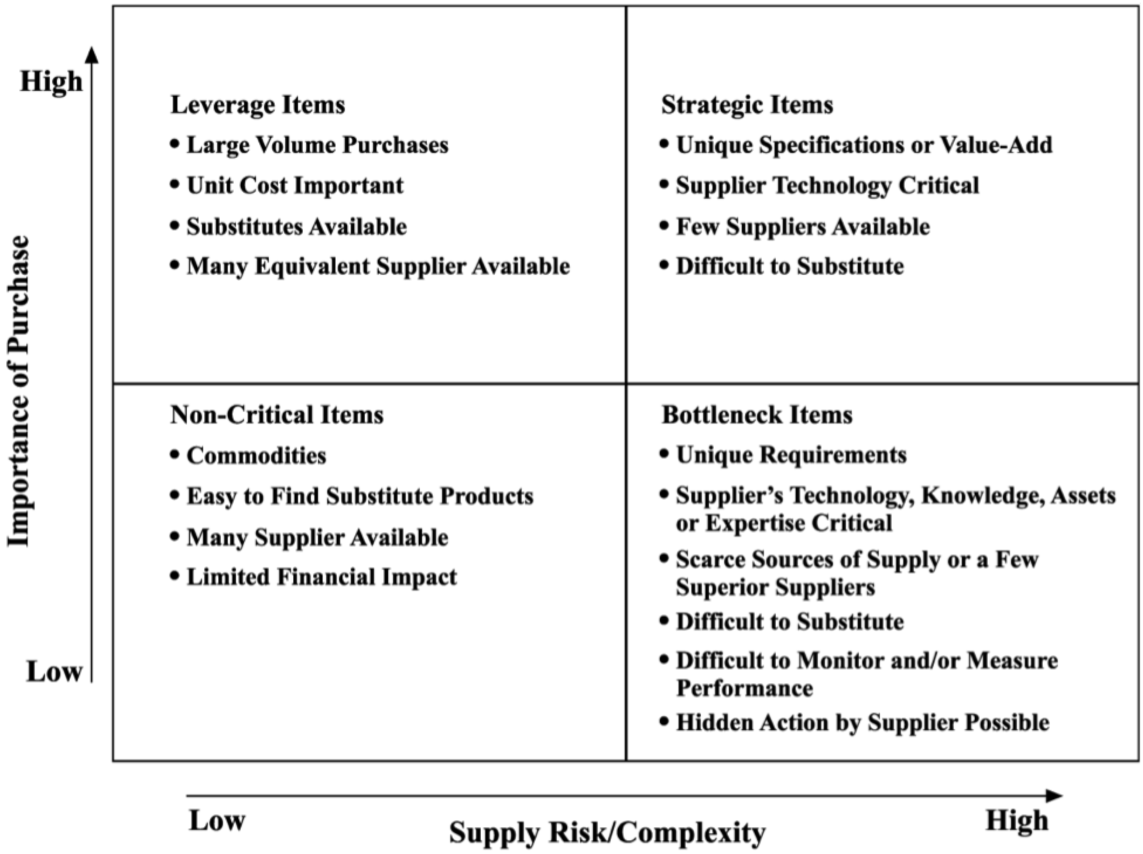

Figure 20: Kraljic categorizes suppliers according to their strategic importance. Muokkaa kuva supplier-kohtaiseksi.

Performance and bottle neck suppliers are wanted collaborators in the solution desk model and life-cycle management environment. They might have an issue with their position in the value chain, as Efora sits on the top of it as an integrator.

Bigger suppliers like Konecranes and ABB are building their own solutions for machine fleet optimization and network collaboration. They most likely try to achieve same type of position in the value-chain as Efora. Suppliers need to think of their own position in the collaboration model and either accept it or remain out of the new network collaboration model. In the end Efora has the control of the wholeness and Efora needs to prove suppliers the benefits of the collaboration.

Smaller suppliers who have not done investments on similar operating models probably consider joining Efora's network more attractive than starting to invest on their own solutions. They, as the bigger suppliers, would like to increase their own share of service production, but they do not have that much of a choice in this kind of operating model. They can still get value from the data and analyses VOC can provide to them.

As suppliers too want to increase the service production related to their own machines, Efora needs to prove client the value they get from Efora being an integrator on whole system level. If this is done right the client will not accept suppliers service offerings done past Efora's, but insted will guide suppliers to negotiate with Efora.

Virtual platform for planning the integration breaks could reduce mobilizing unnecessary face-to-face meetings and would also add continuity in the planning. Integration breaks could be followed up and success factors and avoiders could be found. Critical path of work in progress could be monitored and the ramping up indicators be shown in the Virtual Operations Center. (T. Laakso, personal communication, January 23, 2015)

4.4 Summary of case Efora

Interviews conducted give a strong belief to necessity of Virtual Operations Center in maintenance business, and the benefits it can bring. Building a concept and developing features and applications to a VOC is bounded only by creativity and imagination.

Features and applications presented in this chapter were identified to be beneficial and useful for VOC in maintenance of paper, board and pulp manufacturing production lines and sites. Identifying capabilities has been done by case study interviews and so the business benefits, e.g. the money saved or brought in from borader service contracts, need to be clarified separately.

Life-cycle management of production lines can be improved by better data analysis and providing the information to support investement decisions made in the end and beginning of life-cycle. This information can be analysed by maintenance company, client and machine suppliers altogether via VOC. This enables the best possible investment decisions for the manufacturing company.

Demand of the maintenance work and spare parts can be forecasted from the history data and the maintenance work order queue. Forecasts are essential in planning the supply and resources and can also be used to optimize and automate spare part warehousing.

Making notifications and orders with smart phones or other mobile devices makes the daily work more effective. It prevents useless movement to make notifications and work orders. It can also improve the quality of data and keep it better up-to-date.

Automated real-time dashboards and history reporting removes the unnecessary work of compiling reports in Excel or other hands-on method. Providing all the dashboards and reports in Virtual Operation Center improves transparency through site network. Providing snapshots of the daily work situation to employees make them more able to adapt to new situations and to guide their own work more effectively. Views of upcoming maintenance breaks can be shared with subcontractors and machine suppliers. This makes them able to offer workforce pro-actively.

eLearning center gathers all the necessary use and maintenance manuals and other relevant documents and offers them via the VOC. It can be used to transform technical knowledge from Efora to SE's operators and process knowledge from operators to Efora's technicians. Managing silent knowledge can also be supported by learning center by catching and sharing it via VOC.

Virtual solution desk is a common communication interface for maintenance company, client and key machine suppliers. Root cause analysis and investment decisions can be done together with client and machine suppliers. All the necessary information related to the case under investigation can be shared via Virtual Operation Center's Virtual solution desk.

Features discussed in case Efora are to be used by Efora's own employees but also by clients' and 3rd parties' employees. Different roles can have different features available and different views on the software, but altogether aim to same targets. These targets are to reduce downtime in hours and to improve planning accuracy (%), overall equipment efficiency (%) and the usage of online channels (%).

Virtual Operations Center itself increases the usage of online channels. Usage rate depends on how well Efora's and client's employees and suppliers adapt the new system. The better and more desirable the applications are the higher is usage rate.

5 Conclusions

Virtual Operations Center and operation models around it enables notable improvements in customer value and efficiency. This conclusion can be drawn form both reference case interviews and interviews made in main case Efora.

Virtual Operation Center is built to the base of digital information management features but at least as important are functioning operating models around them. Without new efficient ways to use the new features of VOC they are useless and building and adapting the new ways organisation-wide is a major challenge for change management.

The identified capabilities of VOC needs to be analyzed deeper and prioritized. Few most important capabilities need to be chosen to keep the scope reasonable. Iterative software development is needed in the development as technology evolves so fast.

The processes and ways of work around new features need to be planned and developed into full readiness before launching them one at a time. This prevents the rejection from the field and upper level from the organisation as well. Some new operations models are easier to adopt than others. New applications which empower technicians in the field (e.g. making failure notifications with smart phones) needs strong leadership to be driven to use throughout the organisation. One way to prioritize new development projects is the easiness of adoption to avoid resistance to change.

The position as Industrial Internet forerunner is out there and available. This can be concluded by the reference interviews made with leading edge Finnish companies. Many companies pilot different II-enabled applications and technology like smart glasses or video-assistance on maintenance. Some have successfully implemented applications like putting together failure forecasting models and remote monitoring. It is still reasonable to say that none of the companies have harnessed Industrial Internet to the full potential yet as the technology is also in its infancy.

Industrial Internet solutions requires co-operations from different stakeholders including sensitive data and information sharing to maximize the end client's benefit. There is no simple examples of operations model in network collaboration in Industrial Internet era. Therefore new operations model with client and 3rd parties needs to be formed with learn by doing method. This includes evaluating the existing contracts and benefit sharing in a new way.

Companies should be aware and concerned of other maybe even surprising players in the markets which can seize a position in the value chain capturing part of the business. Without connectivity, capability to refine, use and share the data with relevant partners, machine manufacturers can end up in OEM or component manufacturer position losing the share of growing service business.

6 Discussion

Virtual Operation Center concept was sketched in this study for the purposes of maintenance in paper, board and pulp manufacturing.

Implementing Virtual Operations Center is a strategic choice. The current options are creating it yourself or waiting for other companies to develop commercialized products. A leading position in using Industrial Internet at its best can be achieved by creating an own concept of VOC.

Ongoing standardisation projects on Industrial Internet needs to be considered while building Virtual Operations Center. E.g. Industrial Internet Consortium (formed by GE, Cisco and Intel) is working on standardization and common platforms to speed up technology evolution. Companies which decide to invest in their own II systems need to ensure they do not build a system which cannot later be integrated to new standards.

Industrial Internet applications in maintenance business combine elements from the areas of operations management, service innovations, ICT and automation technology. Mastering wholeness these elements form is a challenge for an Industrial Internet engineer and to a CIO. The scale of these areas is quite wide for one expert to handle in-depth. With deep enough understanding of II cornerstones a II engineer is able to hire and source the right capabilities and manage the palette with a right type of cross scientific/industrial team.

Further possible studies on this subject can be listed endlessly. Industrial Internet means after all using Internet for industrial purposes and Virtual Operation Center is a concept which can be developed further with any new capabilities imaginable. It remains to be seen in further studies how Industrial Internet applications affect on business financially. This thesis purpose was to draft the concept of VOC and the financial evaluation and business case calculations need to be done in further studies and projects.

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A Interview structure for the reference companies

1. Does the company have a VOC or similar applications or solutions, what type of?
2. What capabilities or applications does the VOC have?
3. What kind of different versions of VOC exists for different use cases?
4. Why has the VOC been build?
5. What new VOC enabled services have been offered to clients?
6. How has VOC helped company itself or clients to improve their operations and business?
7. Who are the users of VOC (company's own employee, clients, others?)
8. What are the benefits VOC have brought to company and its client?
9. How has the VOC been built?

Focus questions which dug deeper on each topic differed depending on the case.

B Interview structure for the case Efora

1. What are the objectives in developing a VOC?
2. How can Virtual Operation Center be used to develop maintenance operations?
3. What kind of applications should be provided to Efora and the client?
4. What benefits can be achieved from both Efora's and client's point of view?
5. What roles in Efora and client could be the users of VOC?
6. How can VOC and Industrial Internet help in managing production lines life-cycle?
7. How can VOC help to improve the collaboration with client and third parties?
8. How can VOC be used for benchmarking and benchlearning?
9. How can VOC be used to support planning of maintenance?
10. How to grow business with new operations model provided by Virtual Operations Center?

Focus questions which dug deeper on each topic differed depending on the case.

C Benchmarks for maintenance

Preventive/Predictive Maintenance (PM/PdM)		
Application of PM/PdM	PM/PdM hours worked / Total hours worked	>30%
PM/PdM Compliance	PM/PdM Completed / PM/PdM scheduled	>95%
Planned & Scheduled Maintenance Work		
Planned work	Planned work (hours) / Total work (hours)	>80%
Planning Accuracy	Number of Wos completed within estimate (±15%) / Number Wc	>85%
Schedule Compliance	Scheduled Work Completed (hrs) / Scheduled Work (hrs)	>85%
Labor Efficiency	Estimated hours / Actual hours	>85%
WO Aging	Average age of work orders by Priority	
Maintenance Labor (management, effectiveness and optimization) [Maintenance engineering]		
WO Management	Percentage Labor Covered by WO	100%
Resource Management	Overtime / Total time	<5%
Labor Utilization	Labor productive time (wrench time) / Labor paid time	>65%
MTBF	Mean time between failures	Increasing trend
MTTR	Mean time to repair	Decreasing trend
Total plant performance		
Asset Availability	Hours asset performs primary function / Hours asset scheduled t	>95%
Asset Performance	Number of units produced (per period) / Number of units schedu	>95%
Quality of Output	Number of units produced at quality standard / Total number of	>95%
OEE	Overall equipment effectiveness	Availability x Performance x Quality
Stores management and budget and cost control		
Inventory Stockouts		Rare
Inventory Accuracy	Items cycle counted as correct / Total stock items cycle counted	>98%
Repair Factor	Total maintenance and repair cost / Total asset replacement cost	Decreasing trend
Maintenance Costs		Total costs within ±2% of budget
CPU	Cost per unit = Total plan costs / Total units produced	Decreasing trend
Maintenance CPU	Total maintenance costs / Total units produced	Decreasing trend

Figure C1: Benchmarks for maintenance in paper manufacturing (Leiviskä et al. 2009)